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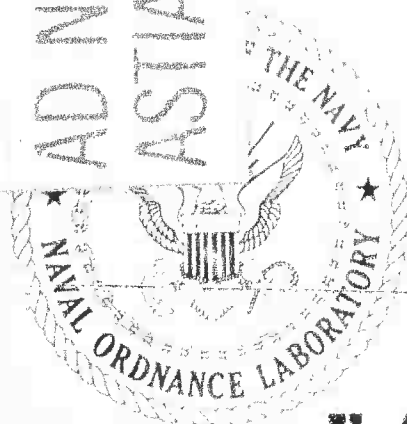
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DEVELOPMENT OF IGNITION ELEMENTS FOR GUIDED
MISSILE IGNITION SYSTEMS

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ABSTRACT: The use of commercial and military service squibs proved to be unsatisfactory for achieving reliable ignition when used in many of the newly developed guided missile ignition systems. The Mks 1, 2, 3, and 4 ignition elements, originally designed for Navy gun primers, were first used by the Allegany Ballistics Laboratory in an attempt to supplant squibs in guided missile ignition systems. The use of these elements lead to the development of the Mks 5, 6 and 7 ignition elements which were designed specifically for guided missile ignition systems.

The Mks 5, 6 and 7 ignition elements were subjected to sensitivity tests, output tests, and direct current functioning time tests under various conditions. All three of the ignition elements produced satisfactory test results when subjected to the given tests.

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NAVORD Report 6283

NAVORD Report 6283

5 March 1959

The work reported herein was done under Task NO 506-925/56015/02040 for the development of guided missile propulsion igniters, as requested by the Bureau of Ordnance. The results and conclusions represent the best opinion of the Laboratory based on the limited scope of the investigation. This information serves as an aid to guided missile ignition system designers. Attention is called to a previous report, (NAVORD Report 6061), entitled, "Evaluation Test Results on Service and Experimental Squibs". The squib evaluations were performed under the same task, and may be used as a comparison with this report on the subject of ignition.

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By direction

NAVORD Report 6283

Contents

	<u>Page</u>
Introduction -----	1
Description of Elements -----	1
Test Procedures -----	3
I. <u>Sensitivity Tests</u> -----	3
II. <u>Direct Current Functioning Time Tests</u> -----	4
III. <u>Output Tests</u> -----	6
Discussion of Results -----	6
Conclusions -----	7
Recommendations -----	8
Acknowledgement -----	8
Symbol Abbreviations -----	9
Appendix -----	10

Illustrations

Table I. Ignition Element Design Data -----	11
Table II. Direct Current Sensitivity of Ignition Elements ---	12
Table III. Electrostatic and Drop Sensitivity of Ignition Elements -----	13
Table IV. Direct Current Functioning Time Tests -----	14
Table V. Mk-2 and 6 Ignition Element Output Test -----	18
Table VI. Unconfined Output Test -----	20
Figure 1. Nomenclature of Ignition Element, Bridgewire Type -----	21
Figure 2. Nomenclature of Ignition Element, Conductive Mixture Type -----	22
Figure 3. Ignition Element Mk 1 Mod 0 -----	23
Figure 4. Ignition Element Mk 2 Mod 0 -----	24
Figure 5. Ignition Element Mk 2 Mod 1 -----	25
Figure 6. Ignition Element Mk 2 Mod 2 -----	26
Figure 7. Ignition Element Mk 3 Mod 0 -----	27
Figure 8. Ignition Element Mk 4 Mod 0 -----	28
Figure 9. Ignition Element Mk 5 Mod 0 -----	29
Figure 10. Ignition Element Mk 6 Mod 0 -----	30
Figure 11. Ignition Element Mk 6 Mod 1 -----	31
Figure 12. Ignition Element Mk 7 Mod 0 -----	32
Figure 13. Basic D.C. Current Limiting Circuit (ion stop)-	33

NAVORD Report 6283

Illustrations (cont'd)

	<u>Page</u>
Figure 14. Basic D. C. Current Limiting Circuit (photocell stop) -----	34
Figure 15. Basic Electrostatic Test Circuitry -----	35
Figure 16. Summary Curves, Ignition Element Direct Current Functioning Time Tests -----	36
Figure 17. Ignition Element Mk 2; Direct Current Functioning Time Test -----	37
Figure 18. Ignition Element Mk 5, Direct Current Functioning Time Test -----	38
Figure 19. Ignition Element Mk 6, Direct Current Functioning Time Test -----	39
Figure 20. Ignition Element Mk 7, Direct Current Functioning Time Test -----	40
Figure 21. Disc Output Test Fixture for Ignition Elements ---	41
Figure 22. Output Test Mk 1 and 5 Ignition Elements -----	42
Figure 23. Output Test Mk 2 and 6 Ignition Elements -----	43
Figure 24. Output Test Mk 7 Ignition Element -----	44
Figure 25. Output Test Mk XB-5A Ignition Element -----	45
Figure 26. Ignition Element Output Test Disc Thickness vs. Hole Volume -----	46
Figure 27. Diaphragm Output Test Fixture for Ignition Element-	47
Figure 28. Unconfined Output Test Fixture -----	48
Figure 29. Short Stock Assembly -----	49
Figure 30. Long Stock Assembly -----	50

NAVORD Report 6283

DEVELOPMENT OF IGNITION ELEMENTS FOR GUIDED MISSILE IGNITION SYSTEMS

INTRODUCTION

In order to obtain more reliable rocket ignition than that obtained with commercial and service squibs, the Bureau of Ordnance requested the Laboratory to modify the rugged and reliable gun primer ignition elements for use in rocket igniters. This work was done in conjunction with rocket igniter development work at the Allegany Ballistics Laboratory.

The properties of three ignition elements were evaluated in order to aid design engineers in selecting the proper ignition device for their particular applications. The elements were evaluated with respect to direct current sensitivity, electrostatic sensitivity, drop sensitivity, direct current functioning time, and output. The functioning times of the elements were also determined under low pressure and temperature conditions or after environmental exposure. The ignition elements have been designated Mk 5, Mk 6 and Mk 7.

Each mark number ignition element and all of its modifications had the same explosive body, and yielded identical performance. The explosive body design only varied with Mark number.

Description of Elements

There are two methods of initiating the explosive in the ignition elements developed by the Laboratory. One method of initiation employs a bridgewire with the initiating charge in contact with the wire. The initiating charge in all of the bridgewire initiated elements is normal lead styphnate which is buttered into a cavity around the bridgewire. An electric current is passed through the bridgewire which heats the wire. The heat is transferred from the wire to the initiation charge which raises this charge to its ignition temperature. The initiation charge in turn transfers its energy to the black powder (or FA-878) booster charge and causes it to ignite. Ignition elements Mks 1, 2, 5, 6, and 7 are bridge-wire elements (see Figure 1).

NAVORD Report 6283

The other method of initiation is accomplished by use of an explosive mixture which conducts electricity. The conductive mixture used in both elements of this type developed by the Laboratory, consists of normal lead styphnate with a small percentage of graphite added to the mixture to increase its electrical conductivity. This explosive mixture is pressed into the element body and is initiated by passing an electric current directly through the mixture. Ignition Elements Mk 3 and Mk 4 are initiated by this method (see Figure 2).

In addition, the elements are made with two different body sizes. The large elements (Ignition Elements Mks 1, 3, and 5) have body dimensions of 0.570 inches diameter by 0.650 inches long. The small elements (Mks 2, 4, 6, and 7) have body dimensions of 0.359 inches diameter by 0.426 inches long. Table I contains additional information on the physical construction of the various elements and their modifications. Figures 3 to 12 show sectional views of the various elements and their modifications.

The original ignition elements (Marks 1, 2, 3, and 4) developed by the Laboratory, were used in Navy gun primers and were evaluated with their respective primers. Therefore, no extensive evaluation was conducted with these elements. Additional information on the characteristics of these elements is available in MIL Specifications (see Appendix item nos. (1), (2), (3), and (4)). Ignition elements Mks 5, 6, and 7 were developed for Guided Missile Ignition Systems and are evaluated in this report.

Ignition Element Mk 5 is a large element which incorporates a one ohm Tophet "C" nichrome bridgewire and a long threaded electrode. In all other respects the Mk 5 element is the same as the Mk 1 element. (Compare Figures 3 and 9, see Table I).

Ignition Element Mk 6 is a small element which incorporates a one ohm Tophet "C" nichrome bridgewire and a long threaded electrode. In all other respects the Mk 6 element is the same as the Mk 2 element. (Compare Figures 4 and 10, see Table I).

Ignition Element Mk 7 is a hi-output element developed with the purpose of incorporating an output equal to or greater than the Mk 5 element in the body size of the Mk 6 element. The only difference between the Mk 6 and Mk 7 elements is that the black powder booster charge has been replaced by a booster charge of FA-878 igniter composition, (see Table I and Figures 10 and 12). (The XB-5A element subjected to the disc output test is the same as the Mk 7 element with a reduced booster charge of 270MG of FA-878 igniter composition).

NAVORD Report 6283

The output of the Mk 1 element equals the Mk 5, and the output of the Mk 2 equals the Mk 6. The only difference involved in each case above is the change in the bridgewire.

Test Procedures

The ignition elements were subjected to three general classes of tests:

I. Sensitivity Tests

- (a) Direct current sensitivity
- (b) Electrostatic sensitivity
- (c) 40 foot drop test

II. Direct Current Functioning Time Tests

- (a) Shelf samples fired at ambient conditions
- (b) Shelf samples fired at low temperature and/or low pressure conditions
- (c) Environmentally conditioned samples fired at ambient conditions

III. Output Tests

- (a) Disc Output test
- (b) Diaphragm output test
- (c) Unconfined output test

The resistances of all ignition elements were recorded previous to firing. A description of each test follows:

I. Sensitivity Tests

- (a) A direct current sensitivity test was performed using the Bruceton "Up-and-Down" Method. Current values were varied by either

NAVORD Report 6283

0.05 or 0.10 amperes increments depending on the magnitude of the current employed. The current values were adjusted by using a resistor of the same average resistance as the element being tested. The basic electrical circuit is shown in Figures 13 and 14. The results are shown in Table II.

(b) An Electrostatic Discharge Sensitivity Test was performed using the Bruceton "Up-and Down" Method to determine the sensitivity of the elements to an accidental discharge of electrostatic energy. A 400 micro-microfarad capacitor was used to approximate the maximum capacitance of the human body. Voltage values were varied by one kilovolt increments. The basic electrical circuit is shown in Figure 15. The results of these tests are given in Table III.

(c) A 40 foot drop test (MIL-Std-302) was performed on the elements to determine if accidental firing would occur under this condition. Each element was assembled with a drop fixture so that the elements hit the striking plate electrode first. The only function of the drop fixture was to insure that all of the elements were oriented in the same fashion during the test. The elements had to be safe to handle, after being dropped, to pass the test. The results are given in Table III.

II. Direct Current Functioning Time Tests

An electronic counter was used to determine the functioning times of the various elements. Two pulses were fed into the timer, and the time interval that elapsed between the pulses was taken as the functioning time.

The start pulse to the timer was obtained by applying the full terminal voltage (24 volts) of the power supply to the timer start channel (see Figures 13 and 14).

Two different methods were used to trigger (pulse) the stop channel in the timer. One method consisted of using the gases expelled from the ignition element to change the resistance across an ionization gap and thus trigger the timer stop circuit (see Figure 13). The second method employed the light emitted by the explosive reaction in the element which was sensed by a photocell and thus triggered the timer stop circuit (see Figure 14).

NAVORD Report 6283

The functioning time tests that were performed are as follows:

(a) Shelf samples of the various ignition elements were fired at ambient conditions with a D. C. power supply at several different current values. The current values were adjusted by using a resistor of the same average resistance as the element being tested. The results are given in Table IV and shown in Figures 16-20.

(b) Certain ignition elements were subjected to one or more of the following atmospheres:

(1) Low temperature

(2) Low pressure

(3) A combination of low temperature and low pressure (approximate simulation of high altitude conditions)

Low pressure conditioning was obtained by placing the elements in a low pressure bomb and evacuating the bomb. Low temperature conditioning was obtained by placing the elements in the low pressure bomb (at ambient pressure, not evacuated) and putting the bomb in a cold box with dry ice. Simulated high altitude conditioning (approx. 100,000 feet equivalent) was obtained by a combination of the two effects. When the desired conditions were reached the elements were fired. The results are given in Table IV and shown in Figures 17 and 19.

(c) Some ignition elements were fired after exposure to one of the following environmental conditions:

(1) JAN Temperature and Humidity Cycle (MIL-Std-304)

(2) High Temperature, High relative humidity (95%)
exposure (NOL test)

(3) High Temperature, ambient relative humidity
exposure (NOL test)

(4) Severe Aircraft Vibration (NOL test)

Results of the functioning time tests conducted with environmentally conditioned samples are given in Table IV.

III. Output Tests

(a) Certain elements were subjected to the Disc Output Test. The test required the ignition elements to fire through a steel disc and ignite black "cannon" powder (see Figure 21). The elements were separated from the discs by air spaces of varying volumes. The air volume was varied by the substitution of spacers with all combinations of hole diameters ($1/8"$, $1/4"$, and $3/8"$) and hole lengths ($1/4"$, $1/2"$, and $3/4"$). The charge tube which held the black powder was $1/2"$ I.D., and also acted as the shear diameter for the discs. In this test, the thickest disc through which a given element would both rupture the disc and ignite the black powder, for a given spacer hole volume, was considered a measure of the output of that element (see Figures 22-26).

(b) The Diaphragm Output Test was similar to the Disc Output Test (see Figure 27). In the Disc Output Test, a $3/4"$ diameter disc with a $1/2"$ shear diameter was used, whereas in the Diaphragm Output Test, a $3 1/4"$ disc (referred to as the diaphragm) with a 3" shear diameter was used. In this test, the thickest diaphragm through which a given element would both rupture the disc and ignite the black powder, for a given spacer hole volume, was considered a measure of that element's output. The results of this test are given in Table V.

(c) The Unconfined Output Test fixture consisted of an open cup with the element mounted in the bottom and an unconfined black "cannon" powder charge surrounded the exposed part of the element (see Figure 28). The ignition elements were held in two different stocks as shown in Figures 29 and 30. The requirement of the test was for the element to ignite the black powder in an essentially unconfined state. The results are given in Table VI.

Discussion of Results

The Mk 5, 6, and 7 ignition elements had very similar characteristics as would be expected. The only significant difference among the three elements was their outputs. The Mk 5 element had a larger black powder booster charge than the Mk 6 element. The Mk 7 element was designed to have an output as large, or greater than, the Mk 5 element contained in the Mk 6 body size. This was accomplished by the use of FA-878 igniter composition in place of the black powder booster charge.

NAVORD Report 6283

The direct current sensitivities of the three elements were between a no-fire point of 0.5 amperes and an all fire point of 0.7 amperes, which was reasonably insensitive.

These ignition elements were very insensitive to the discharge of electrostatic energy which is a desirable safety feature. The Mk 5 element was the most sensitive of the elements, and it could not be initiated with 450,000 ergs. The maximum amount of energy that the human body can hold is believed to be approximately 150,000 ergs, which would not fire these elements.

The Mk 5, 6, and 7 ignition elements exhibited similar functioning time characteristics. All these elements fired in approximately 1.0 millisecond when fired with the recommended firing current of 5.0 amperes D.C., or higher.

The functioning times of the Mk 2 and Mk 6 ignition elements were essentially unchanged when fired under several environmental conditions of low temperature and/or low pressure.

Conclusions

The evaluation of the Mk 5, 6, and 7 ignition elements lead to the following conclusions:

- (a) The elements were insensitive to direct current and electrostatic energy.
- (b) The elements tested exhibited reproducible functioning times at ambient conditions, and are unaffected by environments of low pressure, low temperature, or a combination of both (high altitude conditions).
- (c) The functioning times of the Mk 5, and 6 elements are not affected by storage at 160°F (either high or ambient relative humidity) or the JAN Temperature and Humidity Cycle for periods up to 4 weeks. The Mk 7 element was not subjected to these tests because it incorporated an FA-878 booster charge. In all other respects the Mk 6 and 7 elements are the same. Past surveillance tests of FA-878 in ordnance items have shown that this explosive is essentially unaffected.

NAVORD Report 6283

(d) The functioning times of the Mk 5 and 6 elements are unaffected by the severe Aircraft Vibration test.

(e) The Mk 5 and 6 elements will not fire when dropped 40 feet, and are safe to handle afterwards. (Mk 7 not tested for lack of time.)

Recommendations

These test results were gathered during the development phase of the Mk 5, 6, and 7 ignition elements. It is recommended that PPE lots of these ignition elements be fabricated and a more extensive evaluation undertaken.

Acknowledgement

The authors wish to express their gratitude to Mr. Toy A. Ng and Mr. Phillip Bath, whose help materially aided in the evaluation of the ignition elements.

NAVORD Report 6283

Symbol Abbreviations

I	Current setting (based on \bar{R}) - amperes
\bar{I}	Bruceton 50% current-amperes
KV	Kilovolts
ms	Milliseconds
\bar{R}	Average resistance of a group of squibs - ohms
S	Average deviation
\bar{T}	Average time
\bar{V}	Average voltage

NAVORD Report 6283

Appendix

A. Military Specifications

1. Specification MIL-P-18611 (associated with Mk 1 ignition element)
2. Specification MIL-P-18920 (associated with Mk 2 ignition element)
3. RTP-1402914 (associated with Mk 3 ignition element)
4. RTP-1386146 (associated with Mk 4 ignition element)

Table I
IGNITION ELEMENT DESIGN DATA

Element Type	Bridge (double)		Body Size		Electrode Dimensions				Initiation Charge		FFFG Black Powder - mg	Booster Charge	Resistance Range - ohms
	Wire Diam. (in.)	Single Bridge Length (in.)	Diam. (in.)	Length (in.)	Shank Diam. (in.)	Total Length (in.)	Thd'd Length (in.)	Screw Thread Size	Normal Lead Styphnate + N'cellulose - mg	Normal Lead Styphnate + Graphite - mg			
Bridgewire Material													
Mk-1 Mod 0 LD 479374	0.002	0.100	0.570	0.650	0.174	0.230			8		230		0.10-0.18
Mk-2 Mod 0 LD 479911	0.002	0.076	0.359	0.426	0.174	0.240			14		90		0.08-0.14
Mk-2 Mod 1 LD 299502	0.002	0.076	0.359	0.426	0.164	0.640	0.437	8-32	14		90		0.08-0.14
Mk-2 Mod 2 LD 480067	0.002	0.076	0.359	0.426	0.168 straight knurl	0.945	0.625	8-32	14		90		0.08-0.14
Mk-3 Mod 0 LD 284701			0.570	0.650	0.174	0.240				150			0.75-10.0
Mk-4 Mod 0 LD 291063			0.359	0.426	0.173	0.240				200			0.75-10.0
Mk-5 Mod 0 LD 479427	0.0015	0.100	0.570	0.650	0.164	0.667	0.437	8-32	81		230		1.0-1.35
Mk-6 Mod 0 LD 479425	0.0015	0.076	0.359	0.426	0.168 knurl	0.480	0.343	8-32	14		90		0.75-1.10
Mk-6 Mod 1 LD 480125	0.0015	0.076	0.359	0.426	0.168 straight knurl	0.945	0.625	8-32	14		90		0.75-1.10
Mk-7 Mod 0 LD 479880	0.0015	0.076	0.359	0.426	0.168 straight knurl	0.480	0.343	8-32	14			570	0.75-1.10

NAVORD Report 6283

Table II

DIRECT CURRENT SENSITIVITY OF IGNITION ELEMENTS

Ignition Element	\bar{R} ohms	<u>Bruceton</u> \bar{I} amps	S amps	No-fire I amps	All Fire I amps	Sample Size	Remarks
Mk-1	0.132	2.06	0.04	1.9	2.2	23	Shelf samples
Mk-2	0.098	2.64	0.19	2.4	2.9	30	Shelf samples
Mk-5	1.12	0.62	0.04	0.50	0.70	20	Shelf samples
Mk-6	1.00	0.612	0.04	0.55	0.65	40	Shelf samples
	1.00	0.571				50	Shelf samples, reliability test, Bruceton 1% point, 1 fired
	1.00	0.654				50	Shelf samples, reliability test, Bruceton 99% point, all fired
Mk-7	1.02	0.63	0.02	0.55	0.70	30	Shelf samples

Table III

ELECTROSTATIC AND DROP SENSITIVITY OF IGNITION ELEMENTS

(C=400 mmfd)									
Electrostatic Sensitivity							40 Ft. Drop Test		
Ignition Element	\bar{V} KV	S KV	Min. Firing Energy Ergs	Sample Size	Remarks	No. of Fires	Sample Size	Remarks	
Mk-5			>450,000	20	3 fired at 20 KV 0 fired at 15 KV all shelf samples	0	20	Shelf samples	
Mk-6	>20		>800,000	20	Shelf samples	0	20	Shelf samples	
Mk-7	>20		>800,000	25	Shelf samples				

NAVORD Report 6283

Table IV

DIRECT CURRENT FUNCTIONING TIME TESTS

Ignition Element	I amps	\bar{T} ms	S ms	Sample Size	Remarks
Mk-2	10.00	2.265	0.092	5	Shelf samples tested at ambient conditions - photocell stop circuit used - $\bar{R} = 0.10$ ohms
	5.00	9.805	0.668	5	
	1.00	13.880	0.718	5	
	3.00	30.267	7.165	1	
Mk-2	10.00	2.010	0.095	5	Shelf samples tested at low pressure (4.5 mm Hg and ambient temperature) - photocell stop circuit used - $R = 0.10$ ohms
	5.00	7.524	0.704	5	
	4.00	13.425	0.715	5	
	3.00	32.098	13.443	5	
Mk-2	10.00	2.148	0.093	5	Shelf samples tested at high altitude conditions (-60°C and 6.5 mm HG) - photocell stop circuit used - $R = 0.10$ ohms
	5.00	7.828	0.798	5	
	4.00	13.227	1.512	5	
	3.00	31.567	6.609	5	
Mk-5	5.00	0.644	0.013	10	Shelf samples tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.12$ ohms
	3.00	2.458	0.233	5	
	2.00	4.804	0.283	5	
	1.50	7.871	0.544	5	
	1.00	15.748	1.432	5	
Mk-5	5.00	0.563	0.025	19	Severe aircraft vibration conditioning - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.13$ ohms
	5.00	0.558	0.022	9	4 weeks JAN cycle conditioning (in gun primer stocks and plugs) tested at ambient conditions - ionization gap stop circuit - $\bar{R} = 1.13$ ohms

NAVORD Report 6283

Table IV (cont'd)

DIRECT CURRENT FUNCTIONING TIME TESTS

Ignition Element	I amps	\bar{T} ms	S ms	Sample Size	Remarks
Mk-5	5.00	0.618	0.093	9	4 weeks JAN cycle conditioning (without gun primer stocks and plugs) - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.03$ ohms
	5.00	0.604	0.207	7	4 weeks 160° F ambient relative humidity conditioning - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.04$ ohms
Mk-6	10.00	0.582	0.061	5	Shelf samples tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.00$ ohms
	7.50	0.638	0.038	5	
	5.00	1.022	0.048	5	
	3.00	1.754	0.179	5	
	2.00	3.631	0.090	5	
	1.40	7.263	1.186	5	
	1.00	18.299	2.567	5	
	0.80	53.295	10.751	5	
	5.00	0.930	0.046	19	Severe aircraft vibration conditioning - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.00$ ohms
	5.00	0.978	0.087	20	2 weeks JAN cycle (without gun primer stocks and plugs) - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 0.97$ ohms

NAVORD Report 6283

Table IV (cont'd)

DIRECT CURRENT FUNCTIONING TIME TESTS

Ignition Element	I amps	\bar{T} ms	S ms	Sample Size	Remarks
Mk-6	5.00	0.960	0.052	18	4 weeks JAN cycle (with gun primer stocks and plugs) - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.03$ ohms
	5.00	0.606	0.026	8	4 weeks JAN cycle (without gun primer stocks and plugs) - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.03$ ohms
	5.00	0.949	0.025	10	4 weeks 160°F 95% relative humidity conditioning (without gun primer stocks and plugs) - tested at ambient conditions - ionization gap stop circuit used - $\bar{R} = 1.02$ ohms
	5.00	0.602	0.048	7	4 weeks 160°F ambient relative humidity conditioning (without gun primer stocks and plugs) - tested at ambient conditions - ionization gap stop circuit used - $R = 0.75$
	5.00	0.916	0.055	5	Shelf samples tested at high
	3.00	1.917	0.146	5	altitude conditions (-54°C and
	1.40	8.216	0.428	5	2.5 mm Hg)- photocell stop
	1.00	18.504	6.120	5	circuit used - $\bar{R} = 1.00$ ohms

Table IV (cont'd)

DIRECT CURRENT FUNCTIONING TIME TESTS

Ignition Element	I amps	\bar{T} ms	S ms	Sample Size	Remarks
Mk-6	5.00	1.032	0.049	19	Shelf samples tested at low temperature conditions (-54°C and ambient pressure) - photocell stop circuit used - $\bar{R} = 1.00$ ohms
	3.00	2.014	0.058	4	
	1.40	8.831	0.909	5	
	1.00	26.933	3.334	4	
Mk-7	5.00	1.041	0.099	6	Shelf samples tested at ambient conditions - photocell stop circuit used - $\bar{R} = 1.02$ ohms
	3.00	2.381	0.200	5	
	2.00	3.711	0.212	5	
	1.50	7.295	0.497	5	
	1.00	25.173	1.700	5	

NAVORD Report 6283

Table V

MK-2 AND 6 IGNITION ELEMENT OUTPUT TEST

Diaphragm Test (SAE 1010 Steel diaphragms)					
Spacer Thickness (inches)	Hole Diameter (inches)	Spacer Hole Volume (cubic inches)	Diaphragm Thickness (inches)	Go	No Go
1/4	1/8	0.0031	0.010	2	1
			0.020	0	3
			0.030	Not tested	
1/2	1/8	0.0061	0.010	2	1
			0.020	0	3
			0.030	Not tested	
3/4	1/8	0.0092	0.010	2	1
			0.020	0	3
			0.030	Not tested	
1/4	1/4	0.0125	0.010	2	1
			0.020	0	3
			0.030	Not tested	
1/2	1/4	0.0245	0.010	2	1
			0.020	0	3
			0.030	Not tested	
1/4	3/8	0.0276	0.010	2	1
			0.020	0	3
			0.030	Not tested	
3/4	1/4	0.0368	0.010	2	1
			0.020	0	3
			0.030	Not tested	
1/2	3/8	0.0552	0.010	2	1
			0.020	0	3
			0.030	Not tested	

Table V (cont'd)

MARK 7 IGNITION ELEMENT OUTPUT TEST

Diaphragm Test (SAE 1010 Steel Diaphragms)					
Spacer Thickness (inches)	Hole Diameter (inches)	Spacer Hole Volume (cubic inches)	Diaphragm Thickness (inches)	Go	No Go
1/2	1/8	0.0061	0.010	3	0
			0.020	3	0
			0.030	3	0
3/4	1/8	0.0092	0.010	3	0
			0.020	3	0
			0.030	3	0
1/4	1/4	0.0125	0.010	3	0
			0.020	0	3
			0.030	0	3
1/2	1/4	0.0245	0.010	3	0
			0.020	3	0
			0.030	0	3
1/4	3/8	0.0276	0.010	3	0
			0.020	0	3
			0.030	Not tested	
3/4	1/4	0.0368	0.010	3	0
			0.020	3	0
			0.030	3	0
1/2	3/8	0.0552	0.010	3	0
			0.020	3	0
			0.030	1	2

NAVORD Report 6283

Table VI

UNCONFINED OUTPUT TEST

Ignition Element	Stock Type	Amount of Black Powder (ml)	Go	No Go
Mk-2	Short	100	9	1
	Short	75	6	4
	Long	100	10	0
Mk-6	Short	100	10	0
	Long	100	10	0
	Short	75	9	1
	Short	60	5	0
	Short	50	9	2
	Short	30	1	0
	Short	20	1	0
Mk-7	Short	100	10	0
	Long	100	10	0

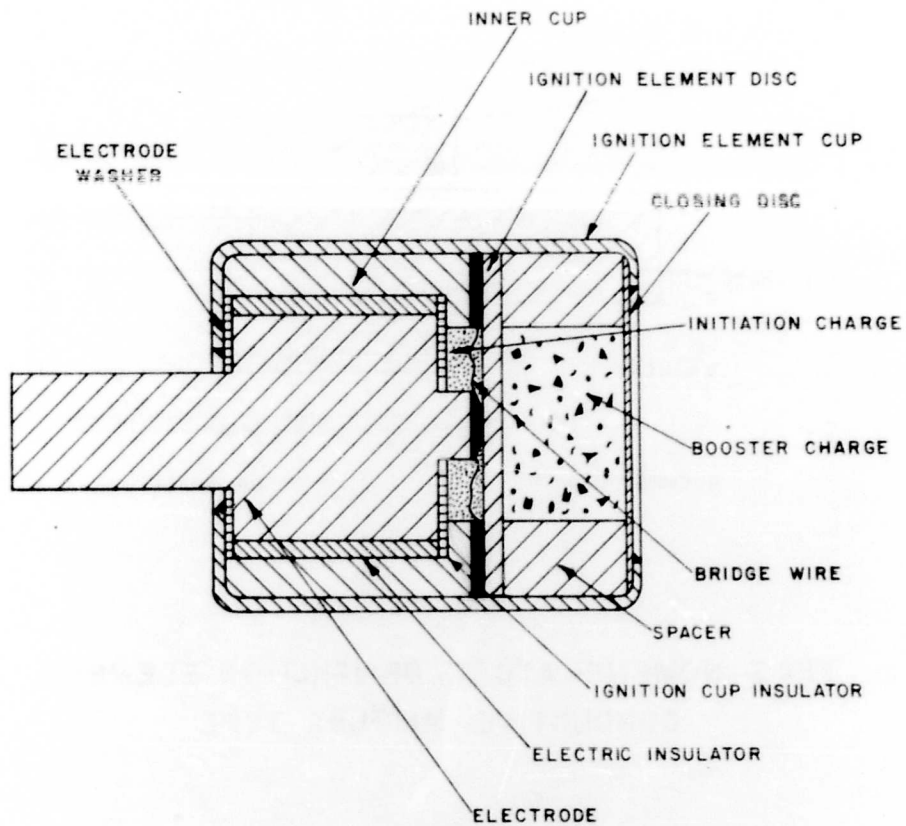


FIG. 1 NOMENCLATURE OF IGNITION ELEMENT
BRIDGE WIRE TYPE

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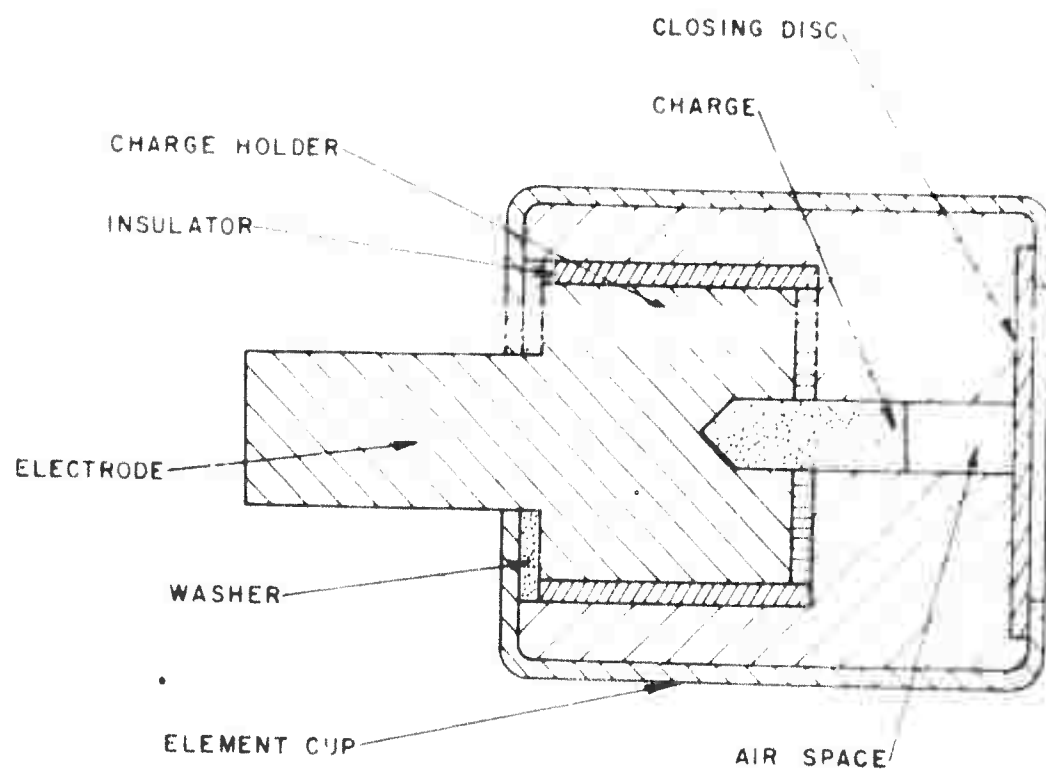
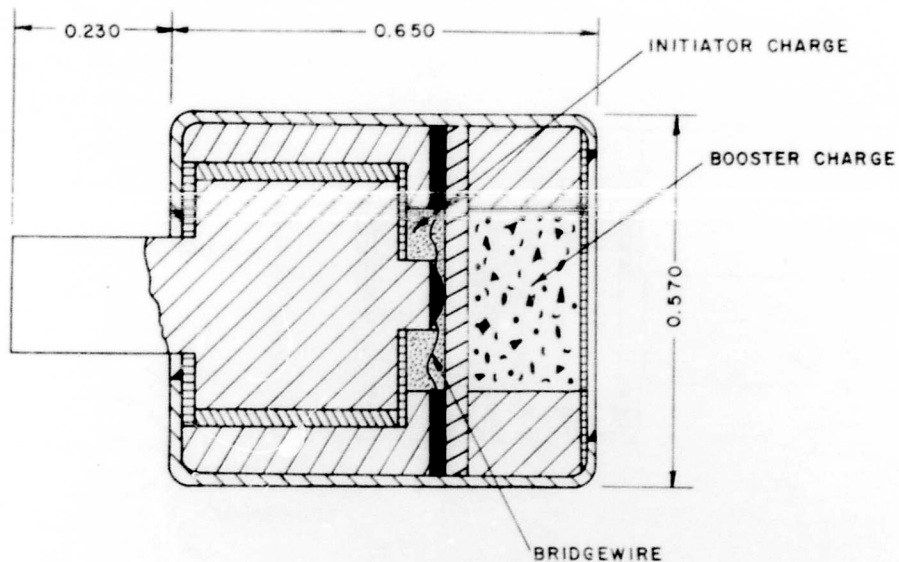


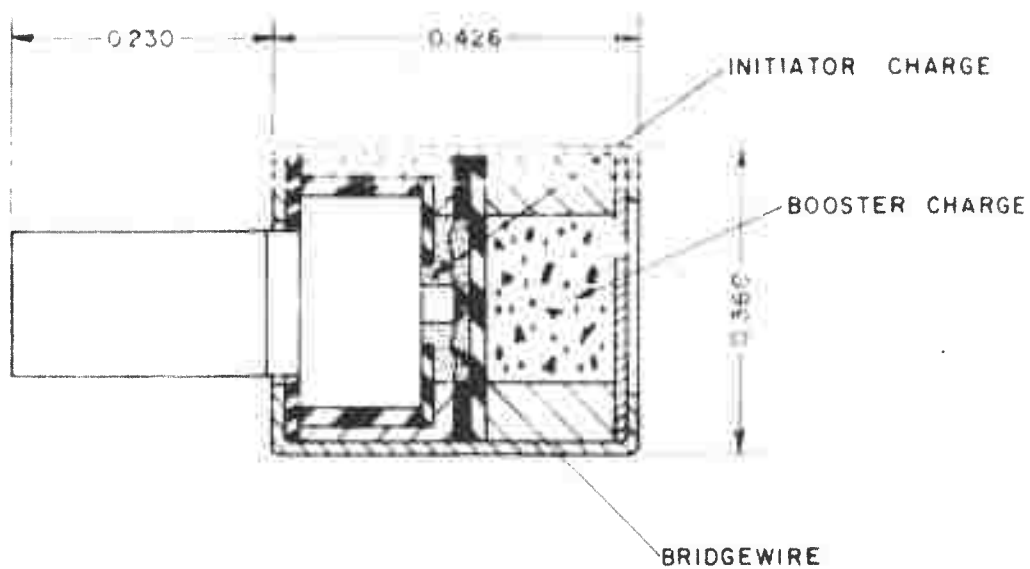
FIG. 2 NOMENCLATURE OF IGNITION ELEMENT
CONDUCTIVE MIXTURE TYPE



1. PT-IR BRIDGEWIRE (0.002 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHNATE AND NITROCELLULOSE), 81 MG
3. FFFG BLACK POWDER BOOSTER CHARGE, 230 MG
4. SEE BUORD LD NO. 479374

FIG. 3 IGNITION ELEMENT MK I MOD 0

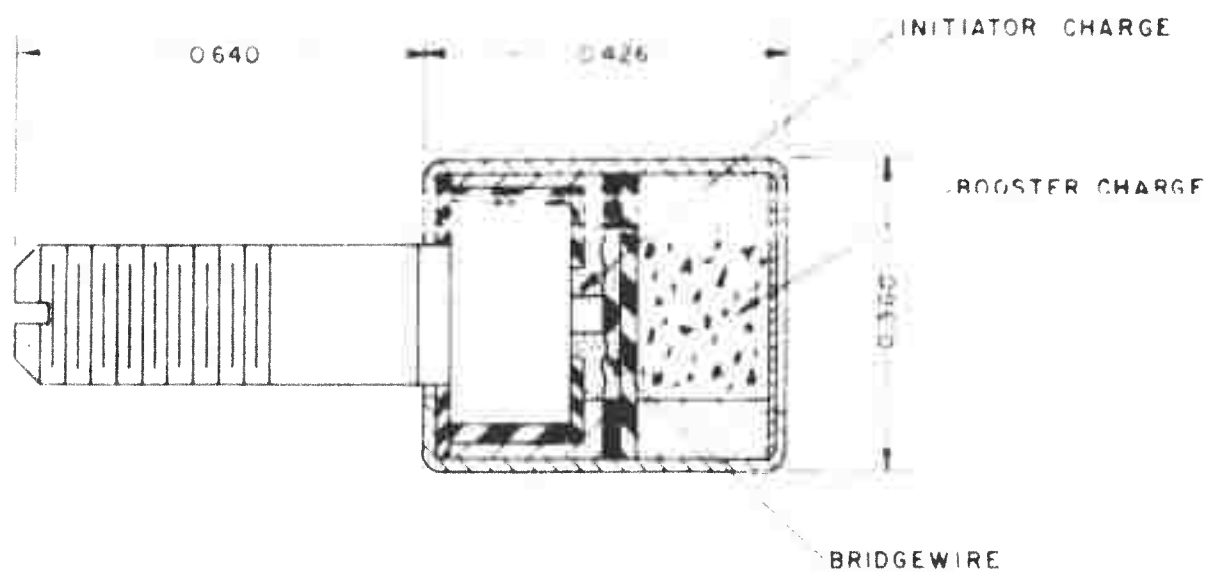
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1. PLATINUM-IRIDIUM BRIDGEWIRE (0.002 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHNATE AND NITROCELLULOSE,(34 MG)
3. FFFG BLACK POWDER BOOSTER CHARGE, 90 MG
4. SEE BUORD LD NO. 479911

FIG. 4 IGNITION ELEMENT MK 2 MOD 0

NAVORD REPORT 6283



1. PLATINUM-IRIDIUM BRIDGEWIRE (0.002 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHNATE AND NITROCELLULOSE), 34 MG
3. FFFG BLACK POWDER BOOSTER CHARGE, 90 MG
4. SEE BUORD LD NO. 299582

FIG. 5 IGNITION ELEMENT MK 2 MOD 1

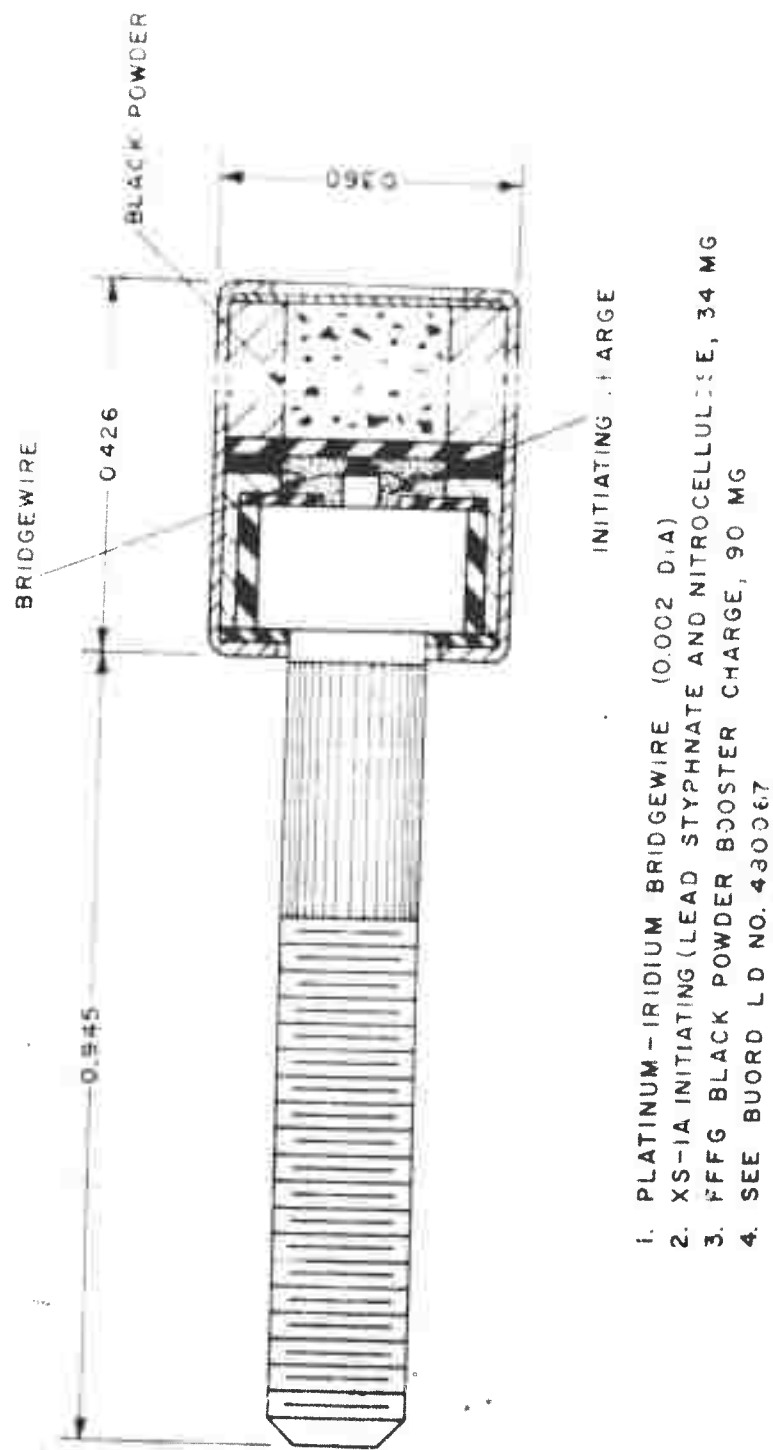
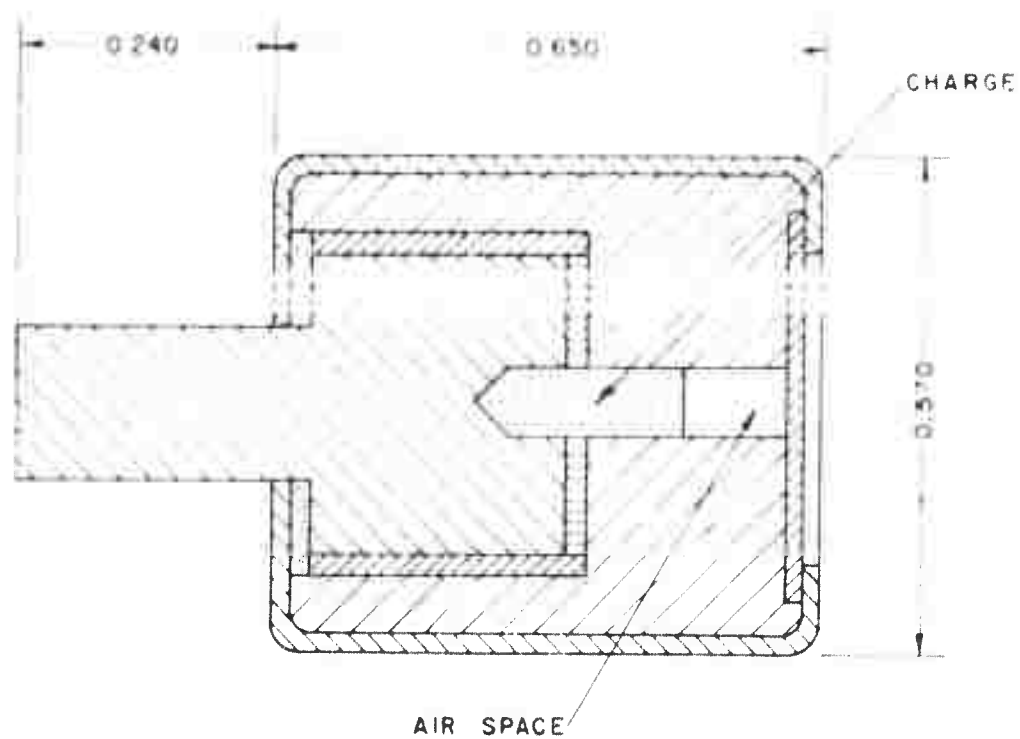


FIG. 6 IGNITION ELEMENT MK 2 MOD 2

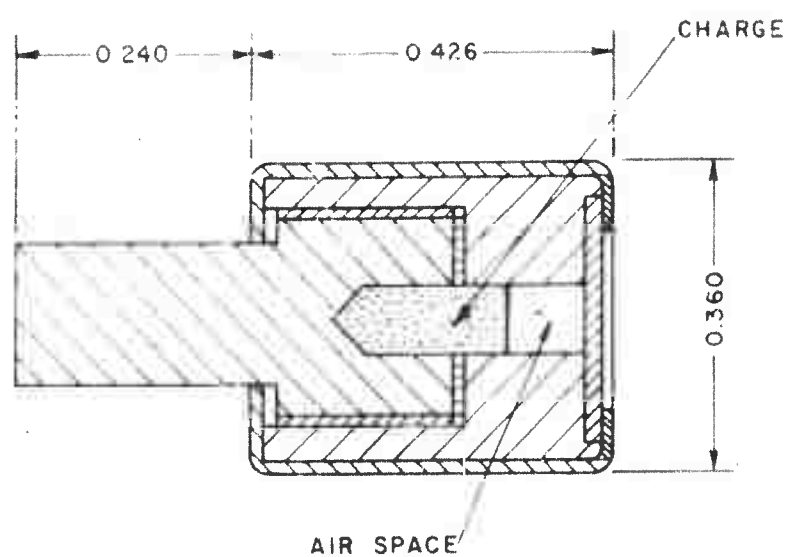
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1. CONDUCTIVE MIXTURE (LEAD STYPHNATE AND GRAPHITE), 150 MG
2. SEE BUORD DWG NO. 1164634

FIG. 7 IGNITION ELEMENT MK 3 MOD 0

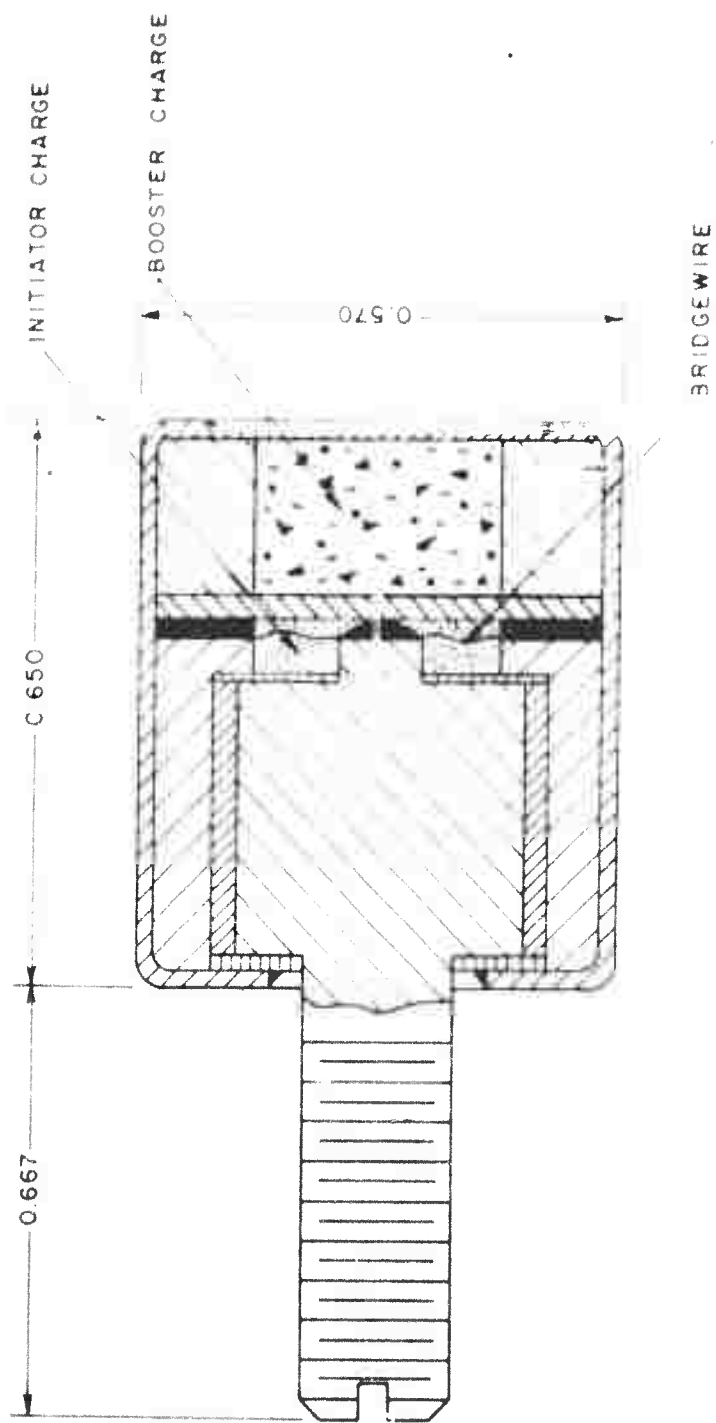
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1. CONDUCTIVE MIXTURE (LEAD STYPHNATE AND GRAPHITE), 200 MG
2. SEE BUORD DWG NO. 1402394

FIG. 8 IGNITION ELEMENT MK 4 MOD 0

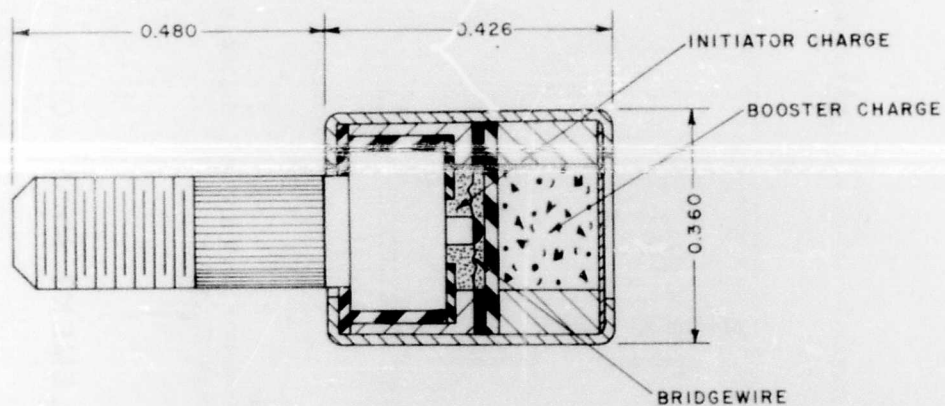
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1. NICHROME BRIDGEWIRE (0.0015 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHATE AND NITR) CELLULOSE, 81 MG)
3. FFFG BLACK POWDER BOOSTER CHARGE, 230 MG
4. SEE BUORD LD NO. 479427

FIG. 9 IGNITION ELEMENT MK 5 MOD 0

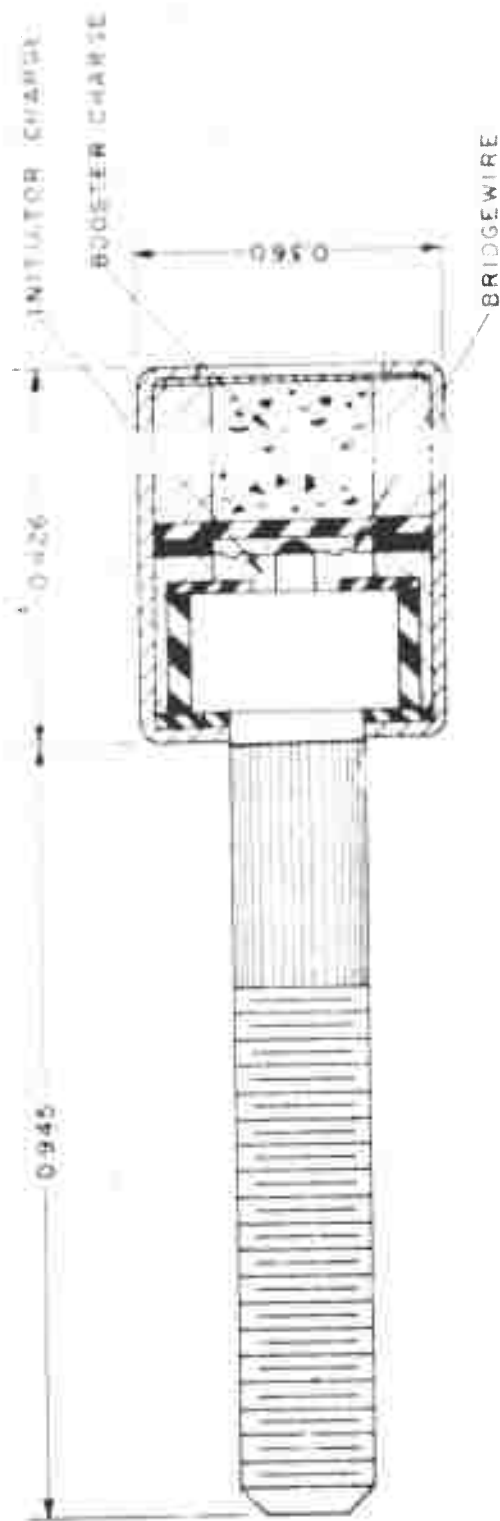
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1. NICHROME BRIDGEWIRE (0.0015 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHNATE AND NITROCELLULOSE, 34 MG)
3. FFFG BLACK POWDER BOOSTER CHARGE, 90 MG
4. SEE BUORD LD NO. 479425

FIG. 10 IGNITION ELEMENT MK 6 MOD 0

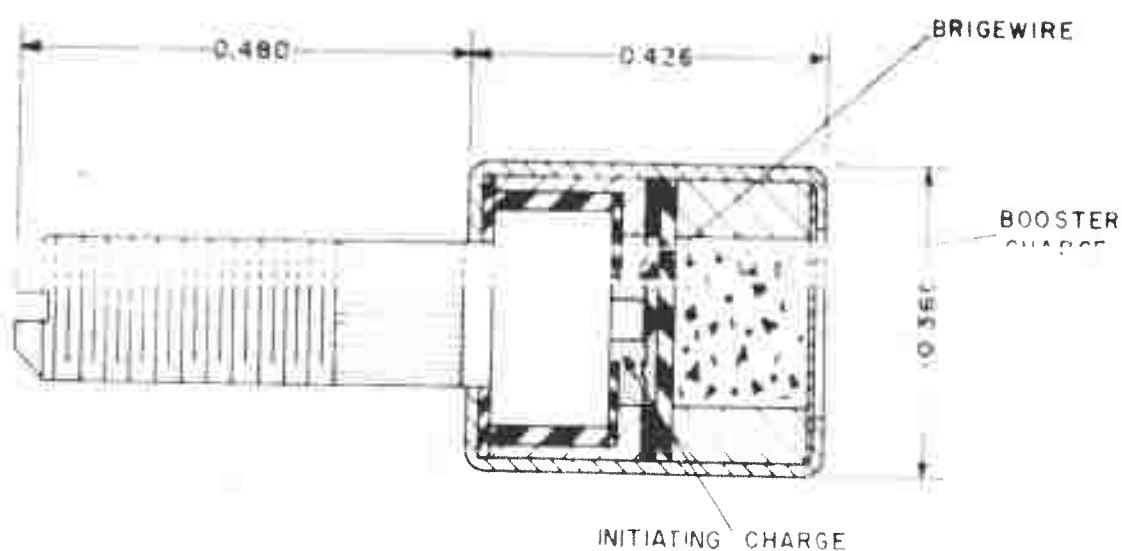
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1. TOPHET C (NICHROME) BRIDGEWIRE (0.0015 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHATE AND NITR ELLULOSE, 34 MG)
3. FFFG BLACK POWDER BOOSTER CHARGE, 90 MG
4. SEE BUORD LD NO. 480125

FIG. 11 IGNITION ELEMENT MK 6 MOD 1

NAVORD REPORT 6283



1. NICHROME BRIDGEWIRE (0.0015 DIA)
2. XS-1A INITIATING CHARGE (LEAD STYPHNATE AND NITROCELLULOSE, 34 MG)
3. FA-878 BOOSTER CHARGE, (570 MG)*
4. SEE BUORD LD NO. 479880

* FA-878 COMPOSITION:

ZIRCONIUM (COARSE) --JAN-Z-399---32.5%
 ZIRCONIUM (FINE) ---JAN-Z-399--- 7.5%
 BARIUM NITRATE ---JAN-B-162 (CLASS A) --20%
 LEAD PEROXIDE---JAN-L-376--- 20%
 PETN -- JAN-P-150 ---20%

FIG. 12 IGNITION ELEMENT MK 7 MOD 0

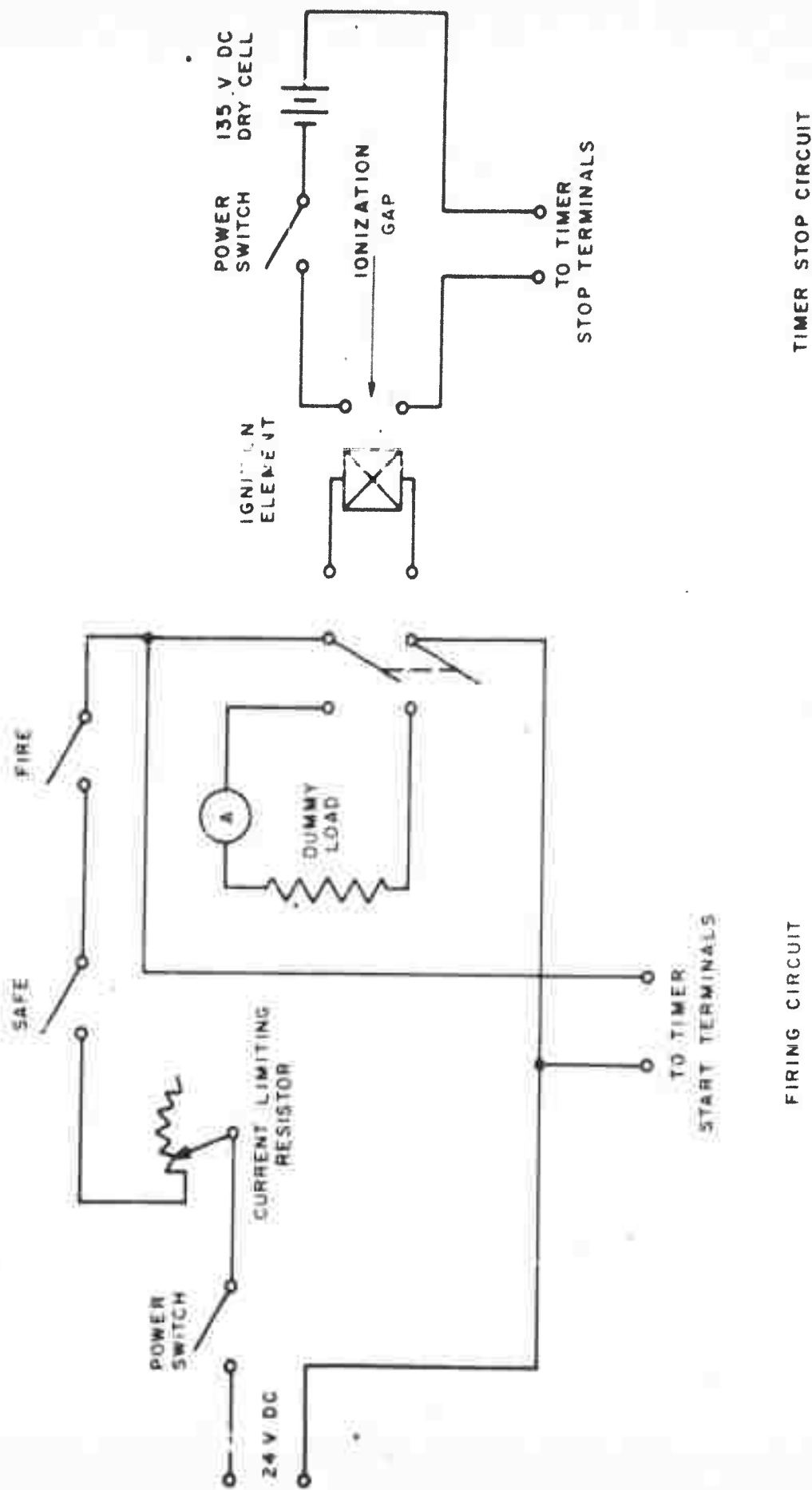


FIG. 13 BASIC DC CURRENT LIMITING CIRCUIT
 TIMER: BERKLEY TIME INTERVAL METER MODEL 5120C

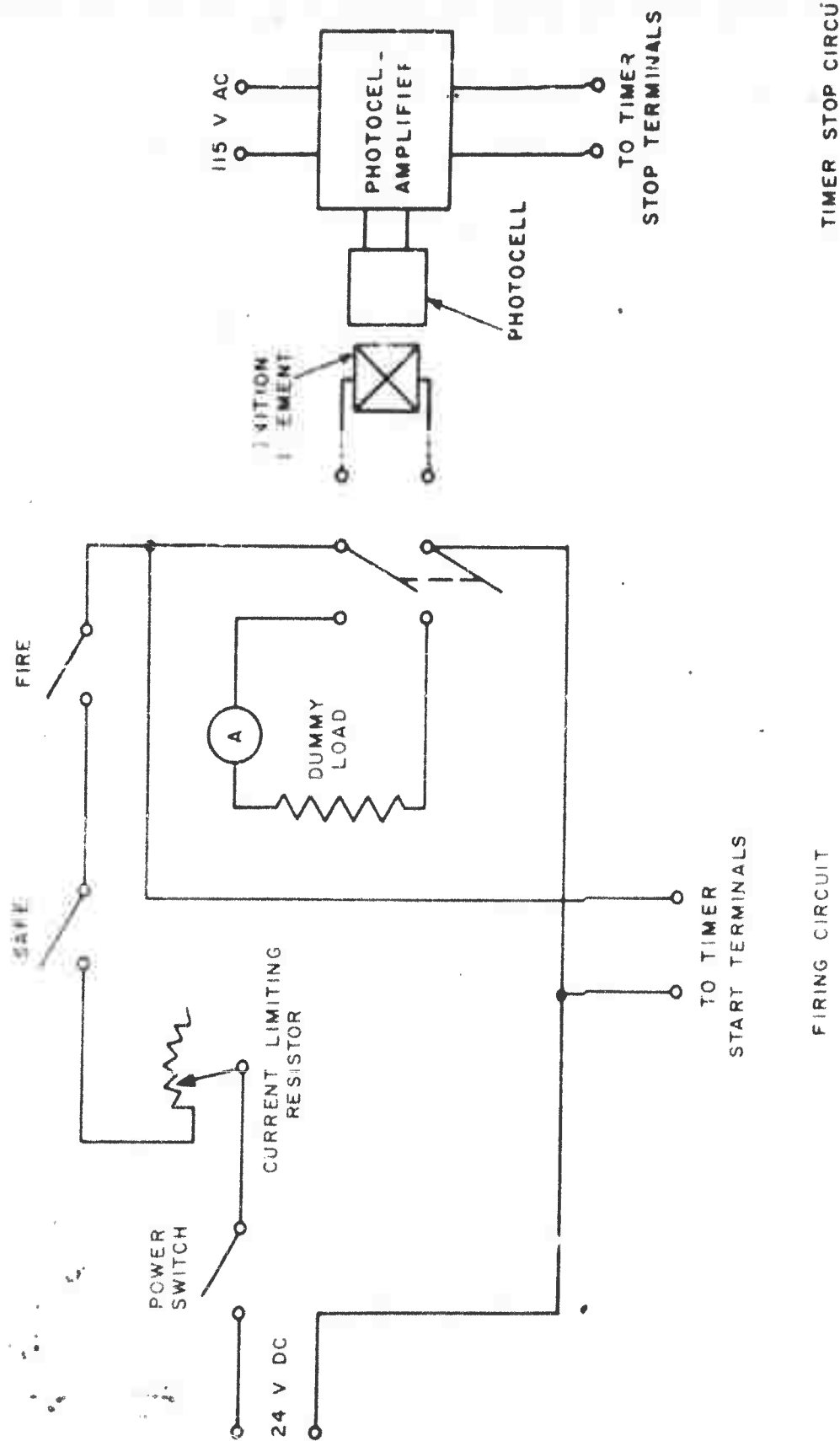


FIG. 14 BASIC DC CURRENT LIMITING CIRCUIT
TIMER: BERKLEY TIME INTERVAL METER MODEL 5120C

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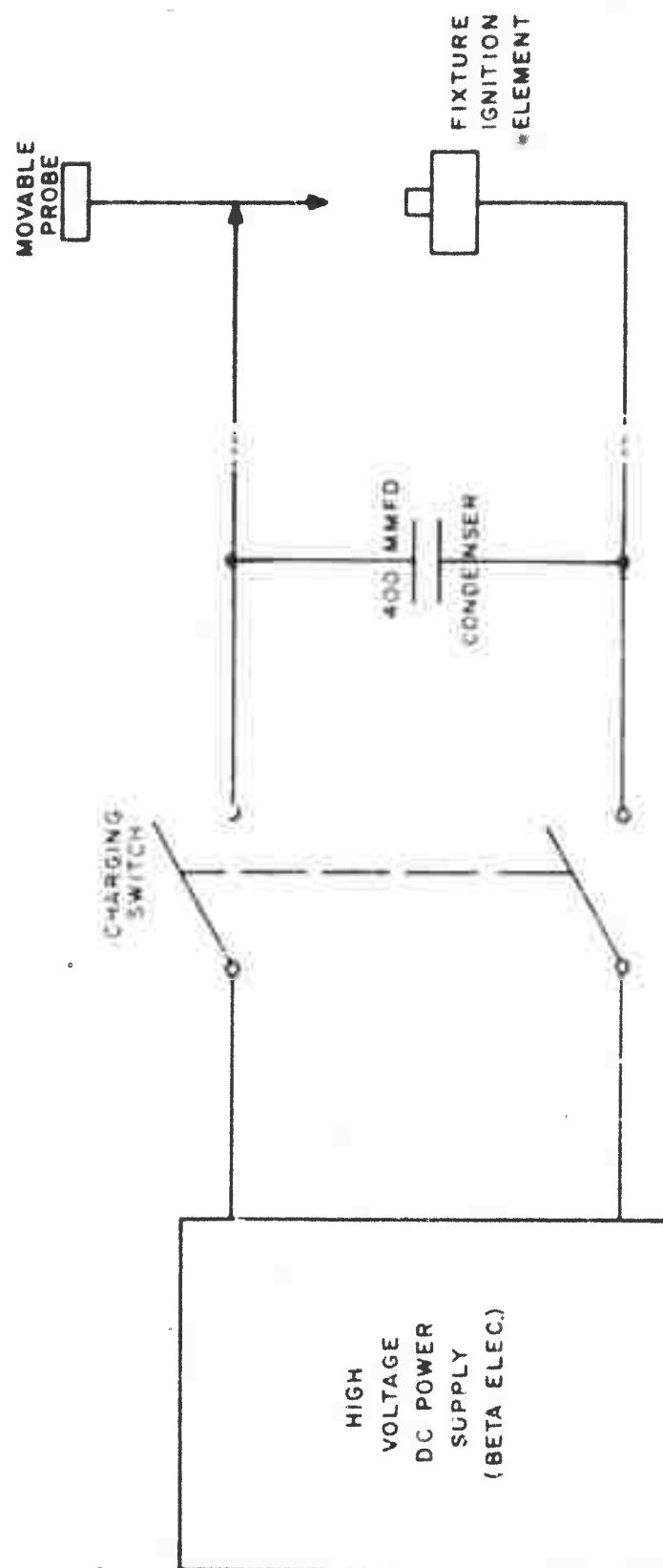


FIG. 15 BASIC ELECTROSTATIC TEST CIRCUITRY

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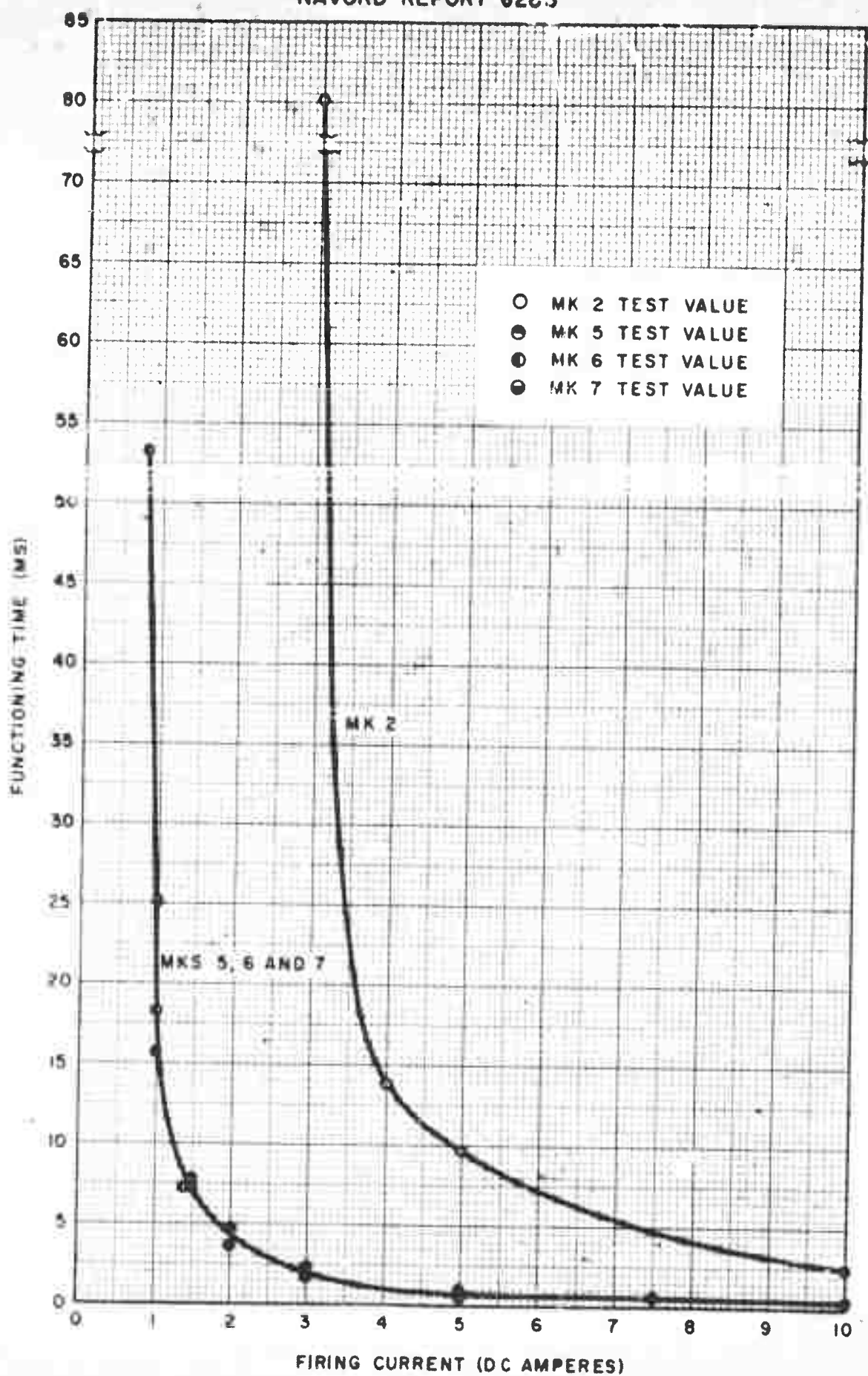


FIG. 16 SUMMARY CURVES
IGNITION ELEMENT DIRECT CURRENT FUNCTIONING TIME TESTS

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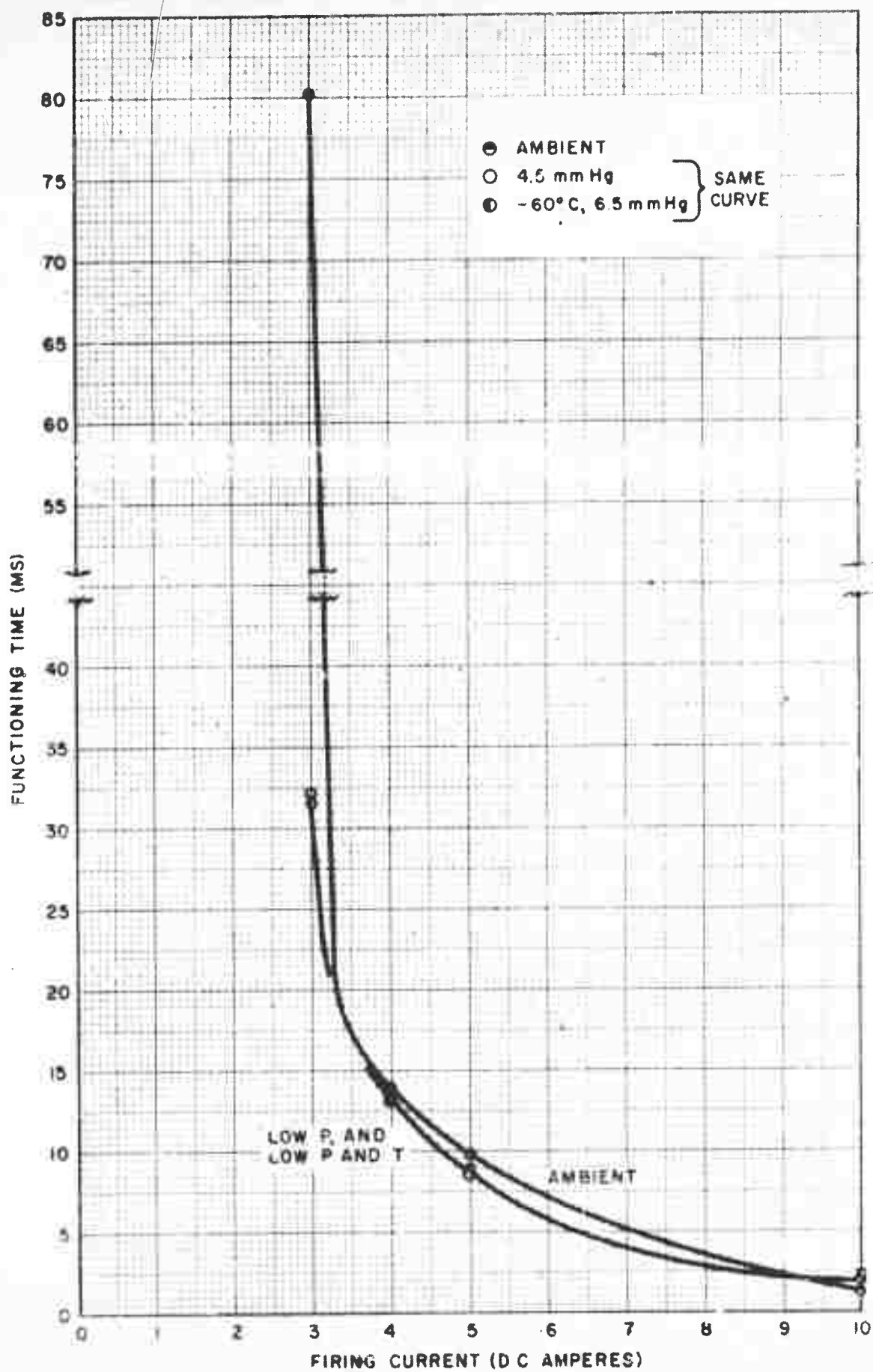


FIG. 17 IGNITION ELEMENT MK2
DIRECT CURRENT FUNCTIONING TIME TEST

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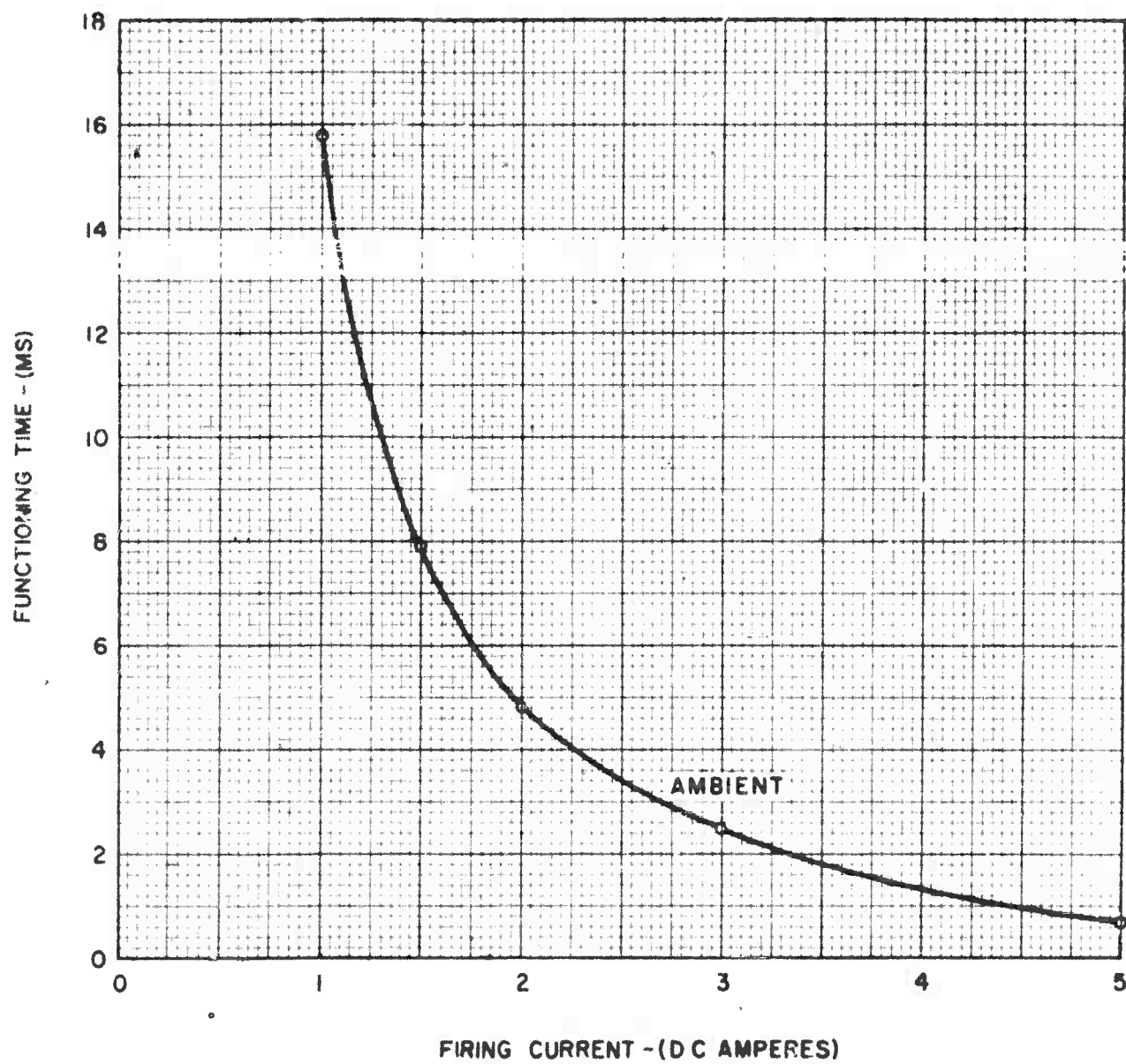


FIG. 18 IGNITION ELEMENT MK 5
DIRECT CURRENT FUNCTIONING TIME TEST

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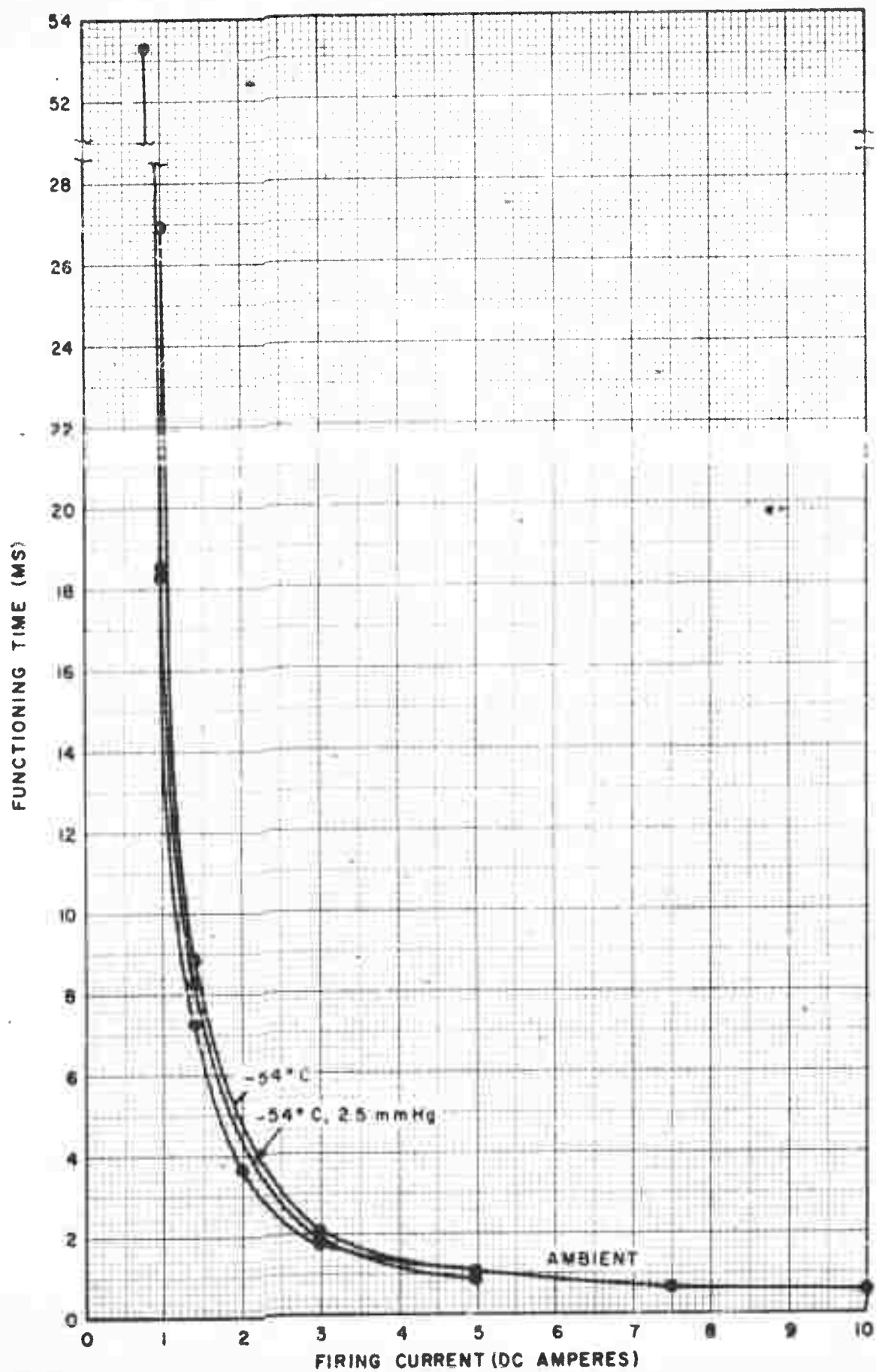


FIG. 19 IGNITION ELEMENT MK 6
DIRECT CURRENT FUNCTIONING TIME TEST

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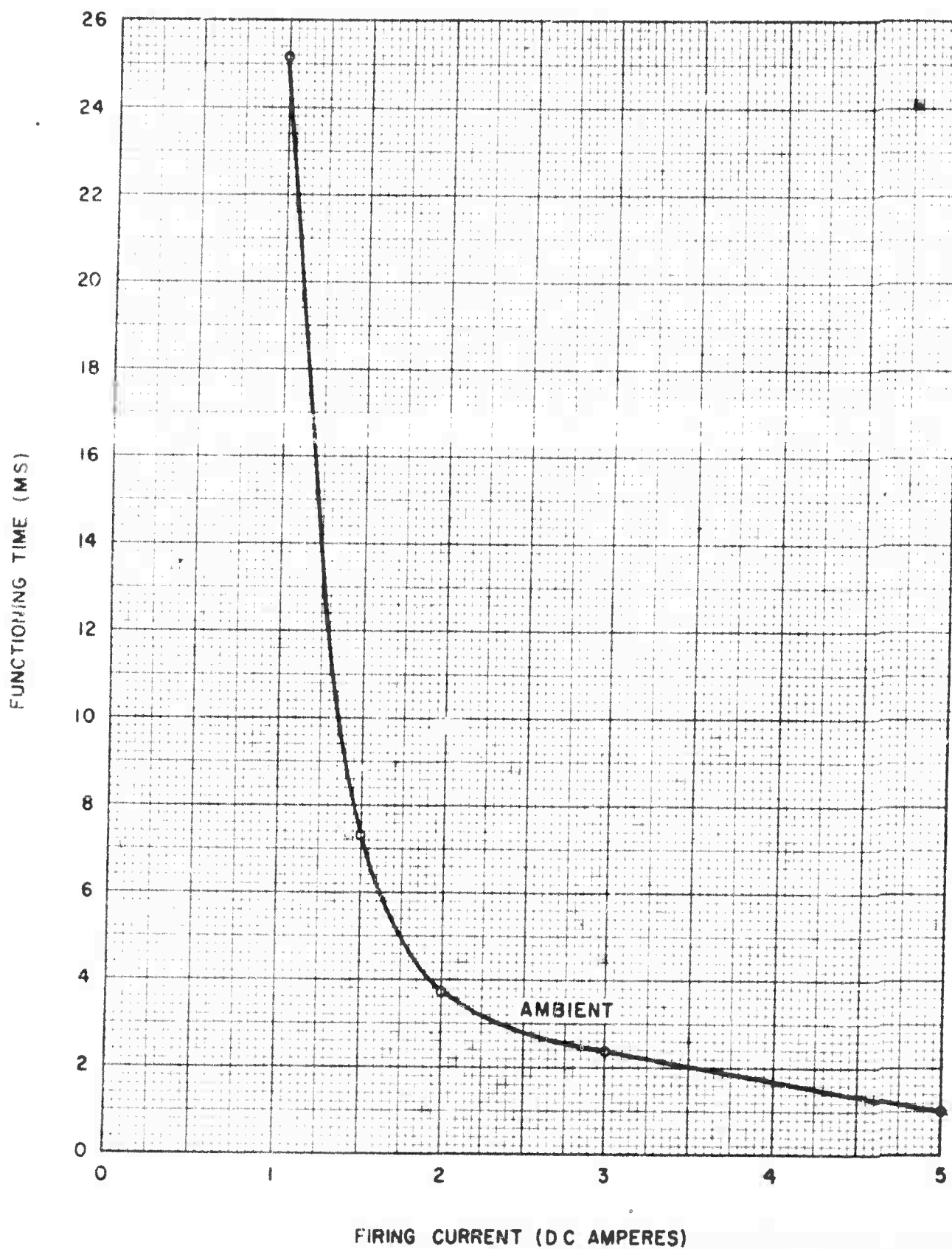


FIG. 20 IGNITION ELEMENT MK 7
DIRECT CURRENT FUNCTIONING TIME TEST

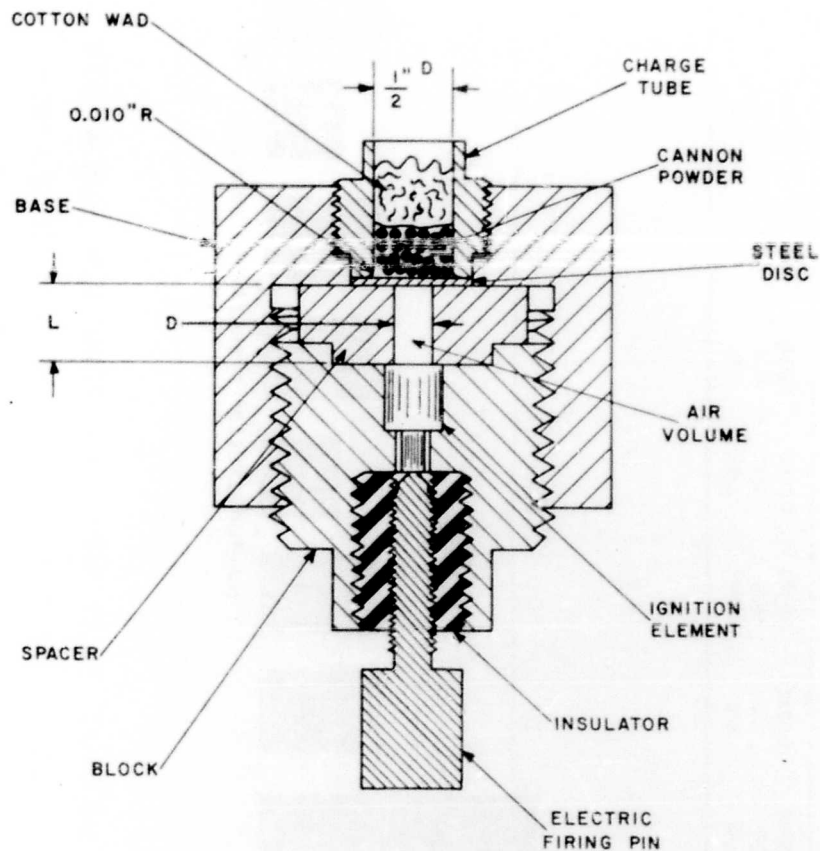


FIG. 21 DISC OUTPUT TEST FIXTURE
FOR IGNITION ELEMENTS

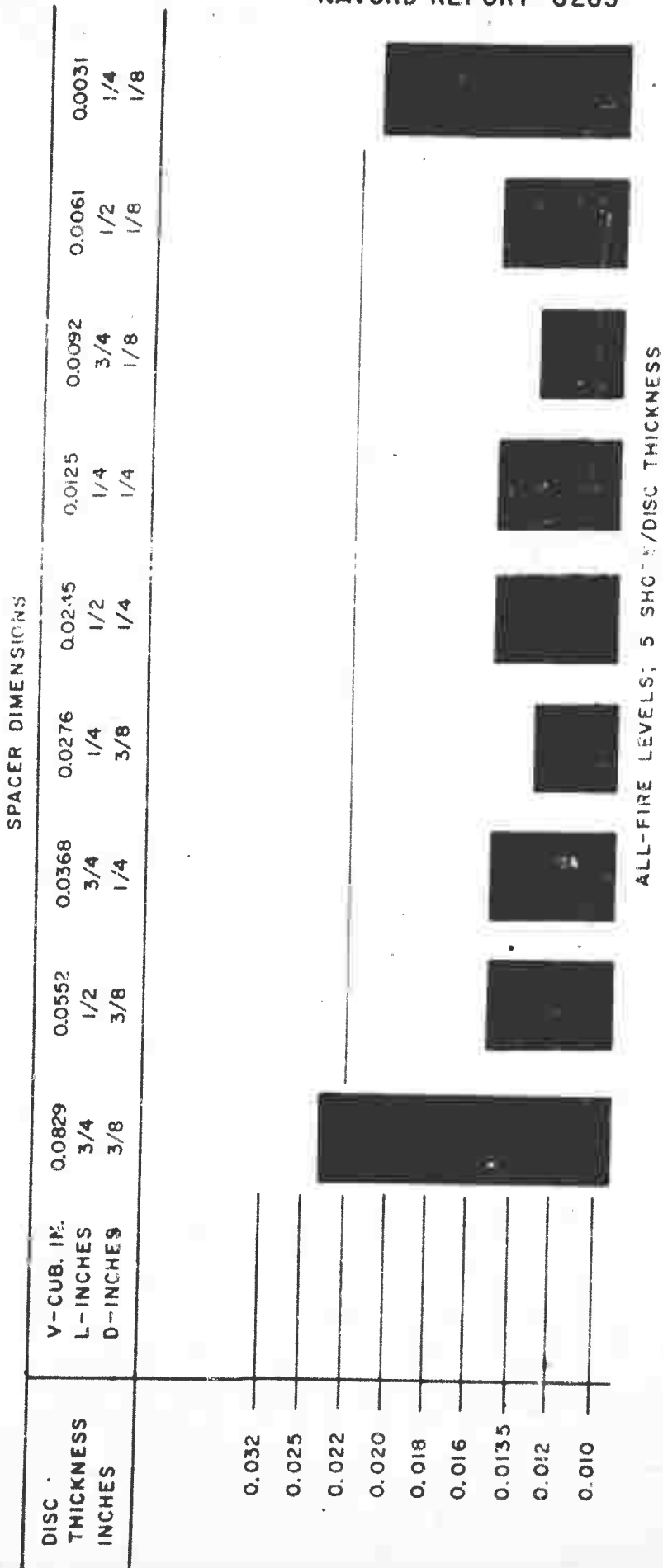


FIG. 22 OUTPUT TEST MK 1 & 5 IGNITION ELEMENTS
(230 MG, FFFG BLACK POWDER BOOSTER CHARGE)
STRIP STEEL DISCS, ROCKWELL B50

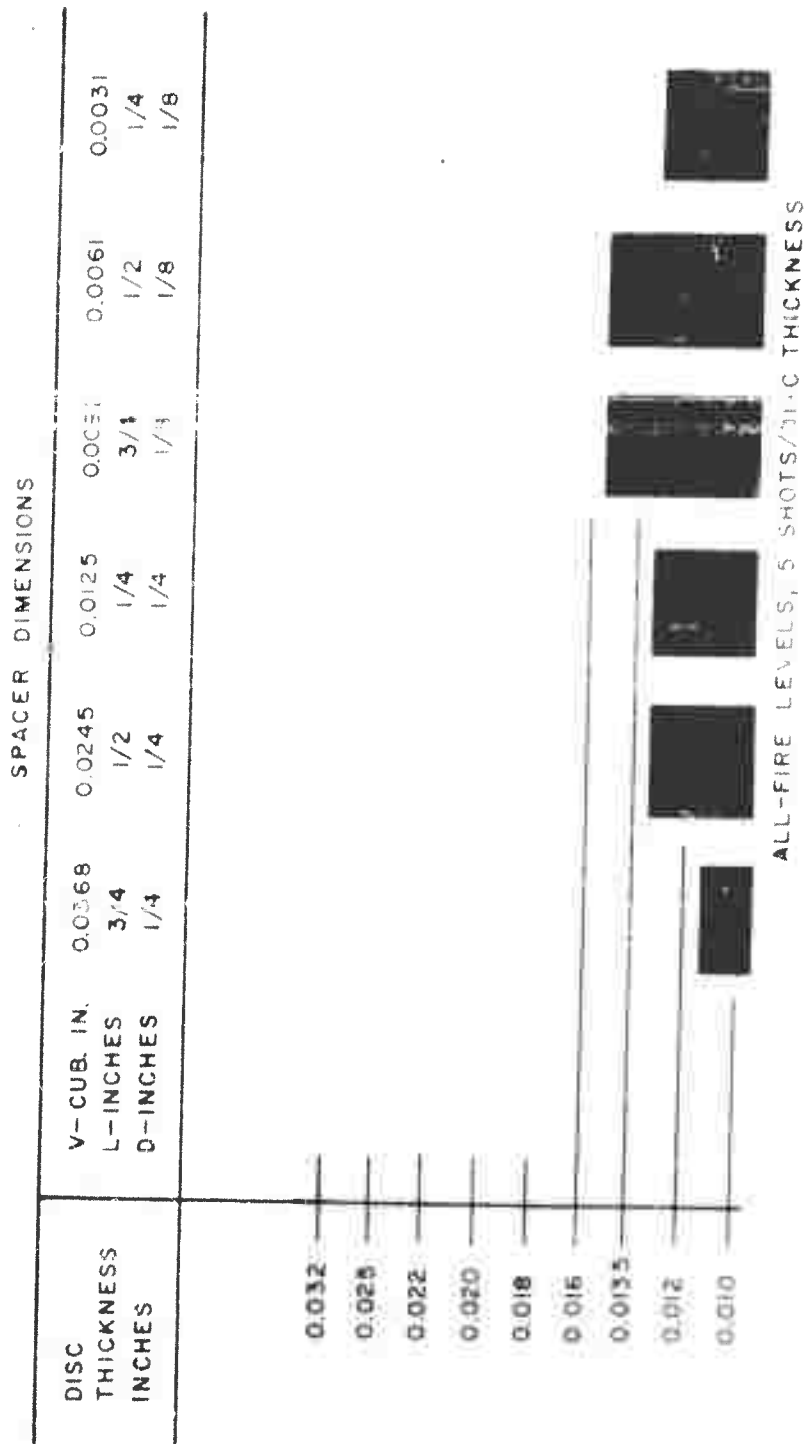


FIG. 23 OUTPUT TEST MK-286 IGNITION ELEMENTS
(90MG, FFFG BLACK POWDER BOOSTER CHARGE)
STRIP STEEL DISCS, ROCKWELL B50

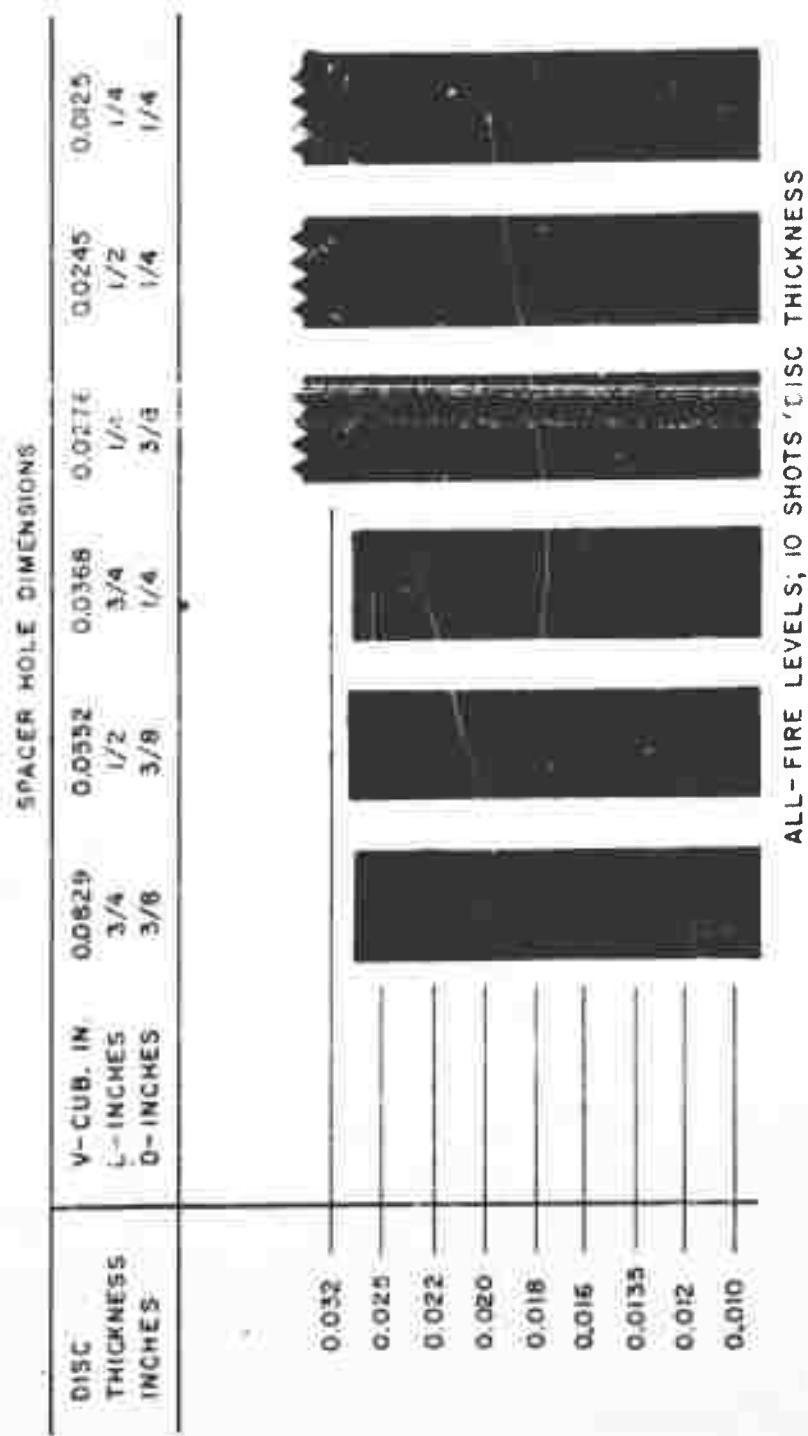


FIG. 24 OUTPUT TEST MK 7 IGNITION ELEMENT

(570 MG FA-878 BOOSTER CHARGE)
STRIP STEEL DISCS, ROCKWELL B50

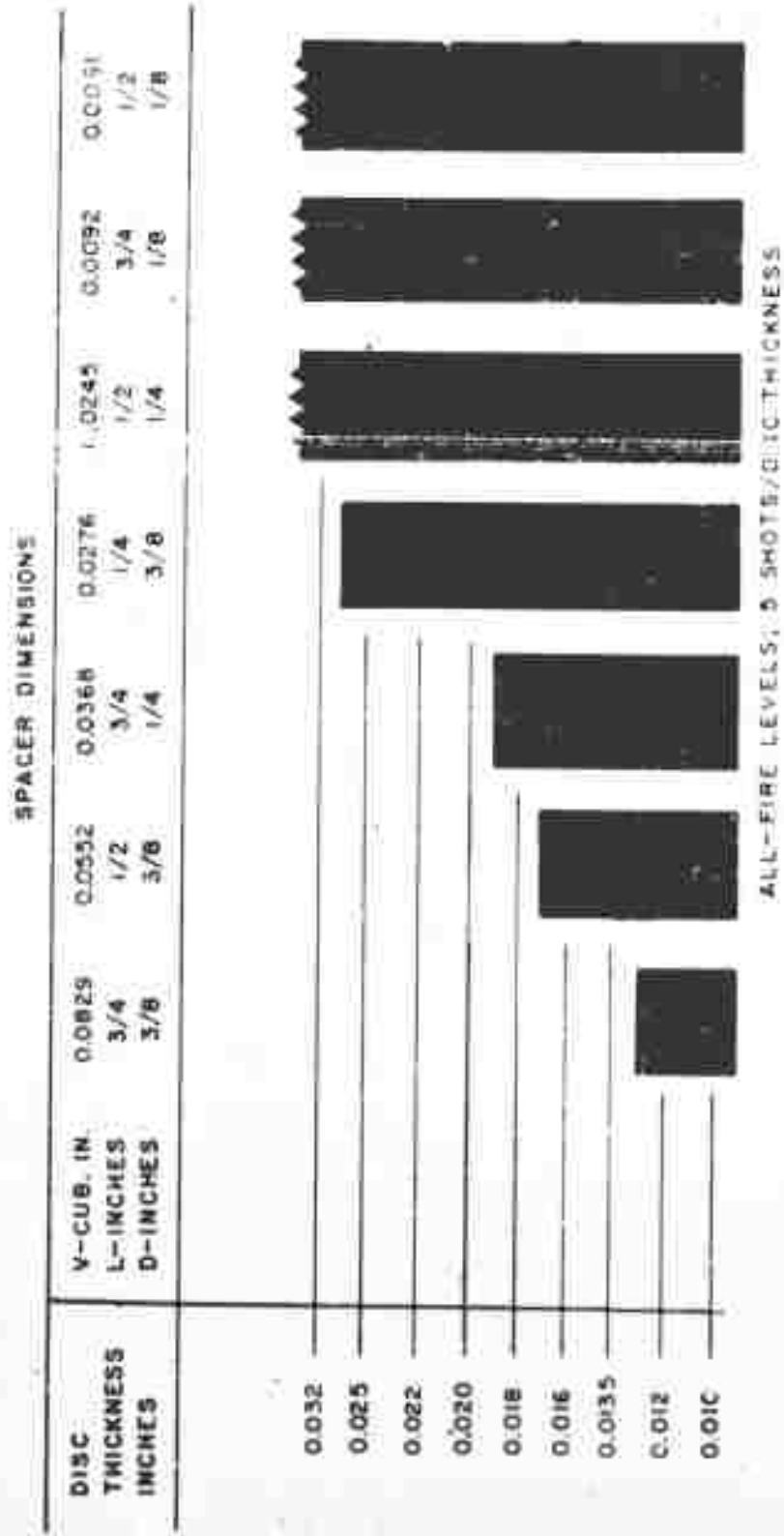


FIG. 25 OUTPUT TEST XB-5A IGNITION ELEMENT
(290MG,FA-878 BOOSTER CHARGE) STRIP STEEL DISCS,
ROCKWELL B 50

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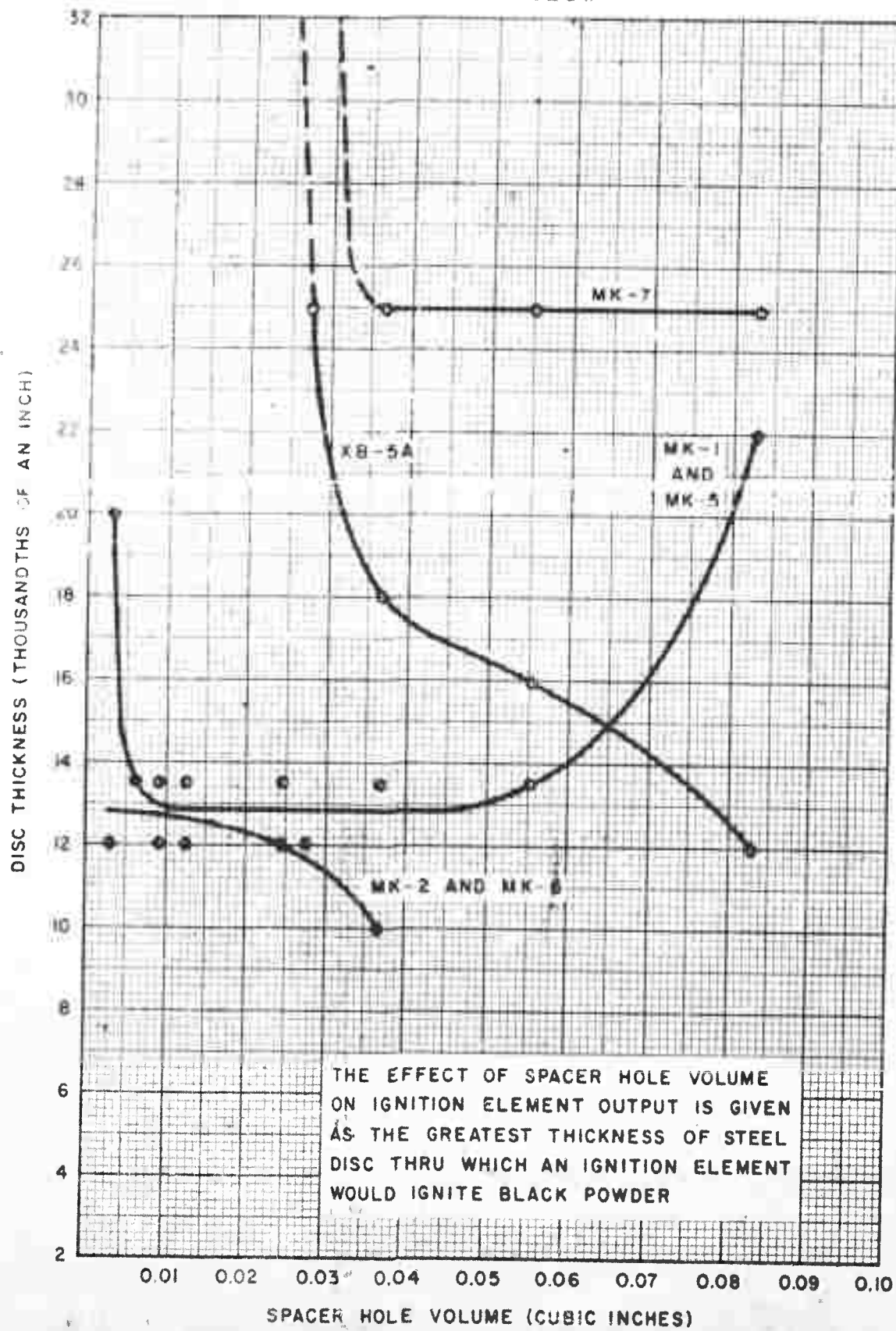


FIG. 26 IGNITION ELEMENT OUTPUT TEST
DISC THICKNESS VS HOLE VOLUME

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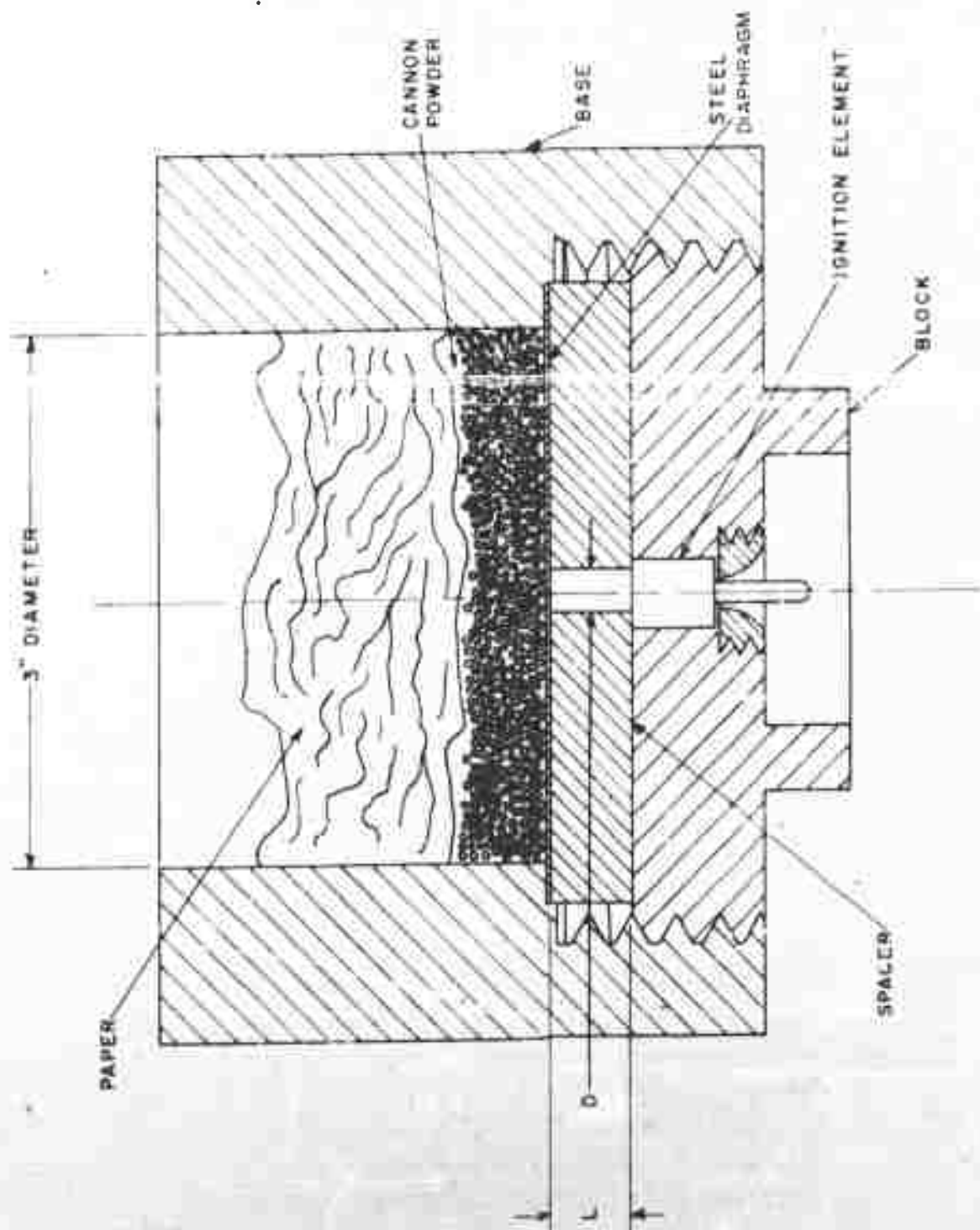


FIG. 27 DIAPHRAM OUTPUT TEST FIXTURE FOR IGNITION ELEMENT

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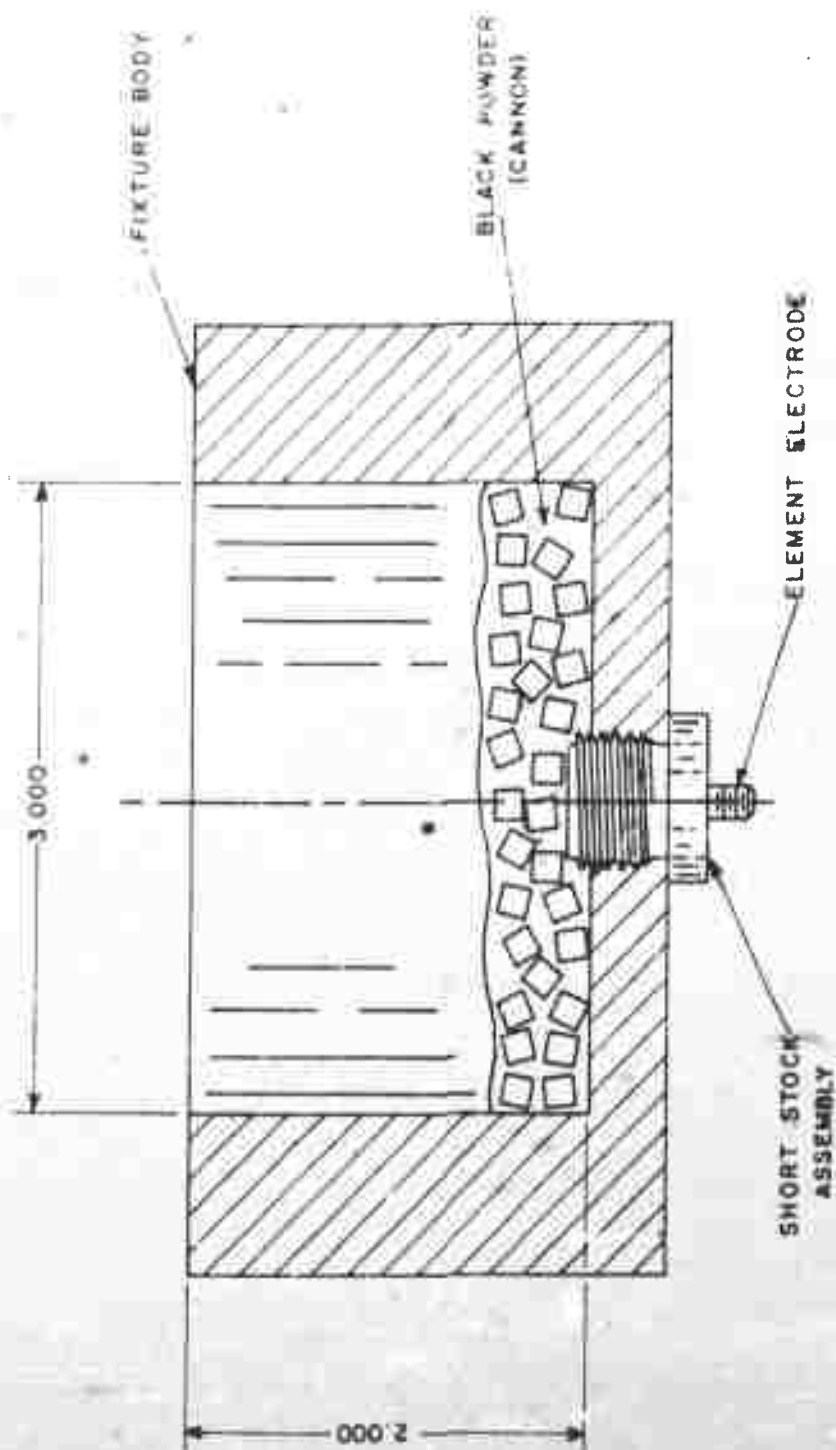


FIG. 28 UNCONFINED OUTPUT TEST FIXTURE

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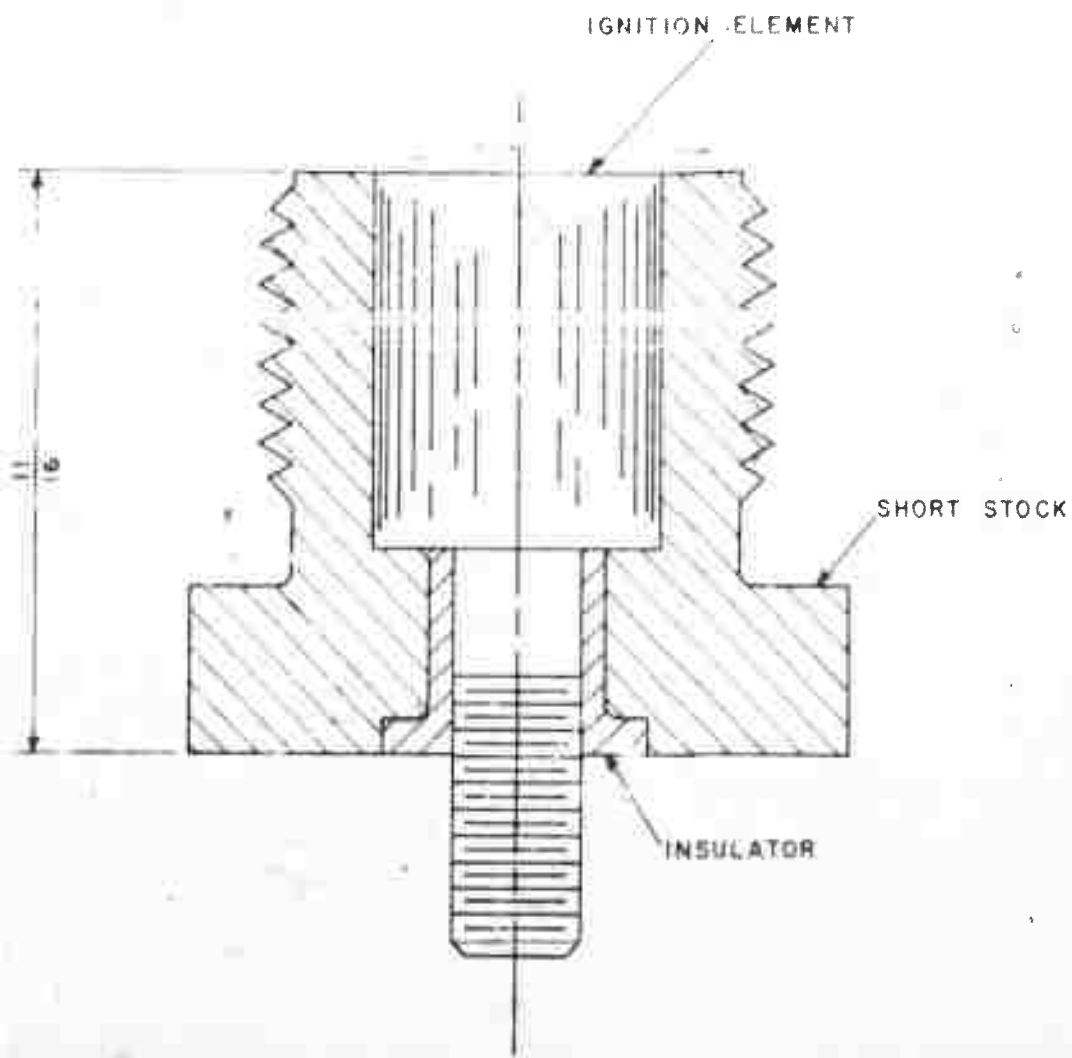


FIG. 29 SHORT STOCK ASSEMBLY

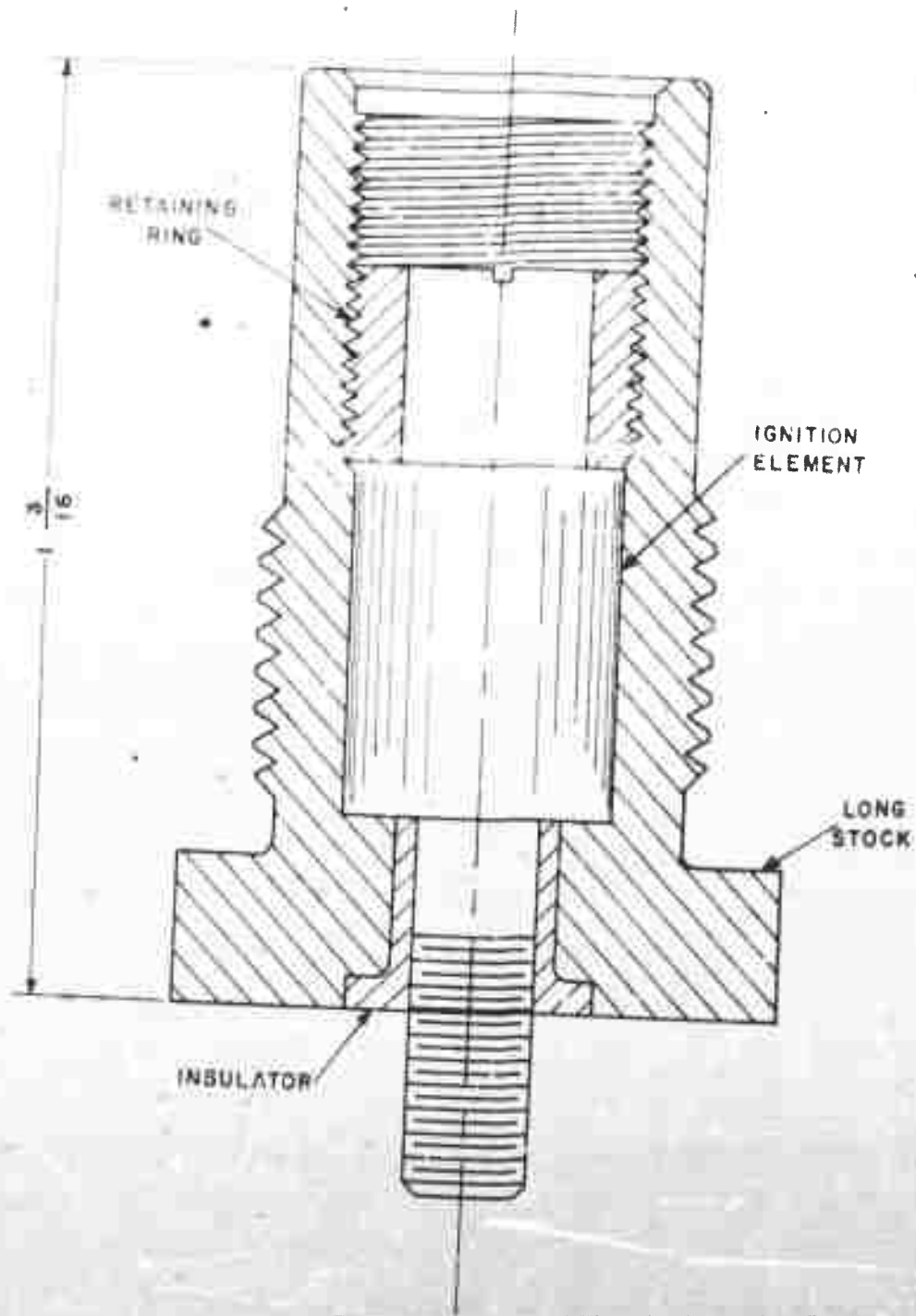


FIG. 30 LONG STOCK ASSEMBLY

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